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Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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Measurement Techniques

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LOCAL ORGANIZATIONS OF THE STANDARDS COMMITTEE AND THE INTRODUCTION OF NEW MEASUREMENT TECHNIQUES

G. N. Sharonov

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 1-3, December, 1960

The work of local organs of the Committee on Standards, Measures and Measuring Instruments is directed toward the realization of the decisions of June (1959) and July (1960). The Plenary Sessions of the Central Committee of the KPSS (Communist Party of the Soviet Union) have established goals for introducing into the national economy new measurement techniques, replacement of old instruments in production by new measuring instruments, improving the quality of instruments now in production and elevating the status of measurement techniques.

In order to improve the organization of work in government control laboratories for measurement techniques, the Committee developed new concepts for organizing all basic types of laboratory work. As of January 1, 1960, Regulation 12-58 was introduced for organizing and carrying out the verification of measures and measuring instruments and control of the status of measurement techniques, and the maintenance of standards and technical specifications. The regulations are intended for further improving the status and introduction of new measurement techniques in the country, the elevation of the organizational and technical role played by local organs of the Committee, the expansion of the regulations and increasing the responsibilities of enterprises and organizations regarding the status of measuring equipment used by them. As of April 1, 1960, Regulation 2-59 was introduced by organs of the Committee concerning government-approved measures and measuring instruments. The regulation provides for a considerable increase in the level of testing and facilitates technical progress and quality of instruments in production. As of January 1, 1960, method instructions were introduced regarding the control and revision work being carried out by local organs of the Committee. The method instructions are designed to further improve the quality of present production and to provide maximum direction on these problems in regard to practical assistance to these enterprises and organizations from the local organs of the Committee.

A typical arrangement of measurement techniques in the central laboratories of enterprises was developed and recommended.

In carrying out the tasks which were set forth in the decisions of the Plenary Sessions of the Central Committee of the Communist Party of the Soviet Union, local organs of the Committee presented to the Central Committees of the Communist Parties of the Union Republics, Provinces and Regions, and National Economic Councils the problems regarding the curtailment of the production of instruments of obsolete design, application of new instruments and increasing the quality of present production. The proposals were to a large extent accepted and are being carried out.

Since July 1, 1959, a considerable number of obsolete instruments being produced by instrument manufacturing plants were either modernized or taken out of production.

Local organs of the Committee together with the instrument production plants have carried out a big program for establishing the production of new measuring instruments reflecting the present level of measurement techniques.

At the same time, the instrument-producing enterprises, with the active participation of government control laboratories for measurement techniques, analyzed the status of matters with respect to the level of instrument production and prepared an additional plan for setting up production of new measuring instruments and taking the obsolete ones out of production.

Among the instruments which have been designated as obsolete and are to be taken out of production are the following:

Type ÉPP-09 automatic recording potentiometer and Type ÉMP-209 automatic recording bridge (Leningrad National Economic Council), which will be replaced by newly designed potentiometers and bridges (including instruments of Class 0.2 instead of 0.5, with an operating time of 0.25 sec instead of 1-8 sec); vertical and horizontal optical indicators (Leningrad National Economic Council); ac potentiometers (Kiev National Economic Council); pyrometric millivoltmeters of Class 1 and 1.5 (Armenian National Economic Council), etc.

The National Economic Councils are providing for the establishment of the production of a large number of new nomenclatures of instruments. Among the number of instruments intended for new production runs are: a series of instruments for measuring pressure and vacuum in aggressive media (Moscow Municipal National Economic Council; instruments intended for automating technological processes in the chemical industry; single-phase electrical meters with a service life of 10 years before repairs and an overload capacity of 300% (Lithuanian National Economic Council); electronic semiconductor-type voltmeter-ammeter-ohmmeter utilizing a printed circuit and having a frequency range of 400 Mc and a wide range of measurement (Estonian National Economic Council); a unified thickness indicator for measuring 0.8-5 mm sheet material(for steel) using isotopes (Estonian National Economic Council); long-range telemetering systems (Leningrad National Economic Council), which include devices for measuring and transmitting over distances of hundreds of kilometers the values for pressure, power, current, voltage, frequency and water level. The new apparatus has interference-rejection and a much higher reliability than the previous one.

In 1960 the government control laboratories for measurement techniques expanded their work on the study of operating properties of instruments. This study was carried out on more than 100 designated instruments. Workers of the organs of departmental offices and instrument-repair enterprises were attracted to these studies. As a result of the studies, a number of concrete proposals were introduced in the instrument-producing enterprises for improving the design and quality of the instruments in production. In many cases these proposals were accepted and utilized with the result that the production quality of many instruments increased substantially.

However, a number of instrument-producing plants still are producing obsolete instruments and low quality instruments, and are slow in setting up production of newly designed instruments, while the local organs of the Committee have not yet taken a sufficiently active role on these problems in the enterprises. The qualifications of workers of the GKL (government control laboratories) who are concerned with the control of new production are in some cases low. Besides this, government inspection on instrument production in the individual plants is organized unsatisfactorily. Inspection on new production runs of instruments is weak in the Gorky, Armenian, Tartar, Tambov, Krasnodarsk GKL's and others.

Local organs of the Committee carried out significant work directed toward the orderly introduction of modern facilities and measuring methods in the enterprises and in the organizations of the separate departments.

In accordance with the proposals authorized by the Committee, the Councils of Ministers of the Union Republics made it mandatory for the National Economic Councils to prepare 1960-1961 prospective plans for replacing obsolete measurement techniques. With the active help of the local organs of the Committee, 75 National Economic Councils prepared such plans. Thus, the introduction of new facilities and measuring methods was made part of the overall plan of the national economy for the introduction of new techniques, which permitted the abrupt expansion of the scale on which new facilities and measuring methods were introduced in industry. For instance, in 1960 in 60 enterprises of the Odessa National Economic Council, as a result of the recommendations of the Odessa GKL, several hundred modern instruments were introduced.

With the direct assistance of the Yaroslav GKL, over 200 new measuring instruments were installed in 22 enterprises.

As a result of proposals of workers of the Lvov GKL made to the Lvov Electric Lamp Plant on a 12-position carousel furnace, the semi-hardening of metal-glass bulbs was placed under continuous control, with automatic regulation of temperature conditions by means of electronic potentiometers, connected in a circuit developed by the Lvov GKL and designed specifically to the specifications of this furnace. As a result rejects in the output operations of the welding of metal-glass bulbs decreased by 4.2%.

Through proposals of fellow workers of the Lvov GKL made to Tannery Plant No. 3, apparatus was prepared and installed for measuring the moisture content of leather hides by means of electrical resistance. By using this apparatus it was possible to establish a new method for unit control of the moisture content of the hides directly in the working areas. As a result of the use of this new method of determining moisture content, rejects during the second quarter of 1960 were reduced 12.3%.

In one of the Gorky plants, the introduction of semi-automatic methods for testing power transformers resulted in a saving of 700,000 rubles; in place of 10 inspectors only one operator is now required.

The VNIIM (D. I. Mendeleyev All-Union Scientific Research Institute of Metrology) carried out measures directed toward the participation of the workers of plant measurements laboratories in the work of introducing new measurement techniques. In particular, the organs of the departmental inspection office, with the assistance of workers of the Testing Laboratory of VNIIM, developed prospective plans for introducing new measurement techniques in 96 of the largest enterprises. These plans designated more than 700 different measures directed toward the introduction of improved facilities and measuring methods, with an overall effect exceeding 7 million rubles. A whole series of measures, the effects of which were not considered on a monetary basis, are of considerable interest relative to increasing the accuracy of measurements, improving quality, etc.

Plans for the introduction of new measurement techniques are being fulfilled successfully. Thus, in the first half of 1960, 166 measures were put into effect with an overall economic saving of over one million rubles.

Considerable work was carried out by local organs of the Committee in expanding and strengthening the instrument repair bases.

Considering that a basic improvement in the repair of measurement apparatus is possible only with a unified, technically-equipped repair base, many of the Union Republic Councils of Ministers, in accordance with proposals authorized by the Committee, decided to transfer the repair of measurement devices under the supervision of the National Economic Councils in order that they could create a strong instrument repair base which would assure rapid and good quality repair of measuring instruments of all types in use in the national economy. As a result, in a number of Union Republics the repair of instruments has improved markedly.

For example, in the Kirgiz SSR the repair of instruments was transferred under the supervision of the National Economic Council and a single instrument repair plant was created which was provided with the necessary equipment. The plant now handles the repair of 50 types of instruments covering all basic types of measurements.

In the Belorussian SSR, the National Economic Council set up a specialized plant "Rempribor" to which were transferred all sectional regional and interregional repair shops. The National Economic Council is constructing a new addition to the plant comprising 5,000 square meters. A large number of different type instruments have been approved for repair in this plant, including radiometric and dosimetric instruments. The "Rempribor" plant is not only expanding the establishment of agreements on technical inspection of instruments but will also make new test equipment, in this case in accordance with documents developed by the Committee.

Many section and district "Ispolkoms" of the Russian Federation decided to construct buildings for instrument repair shops, expand existing facilities, increase the number of stationary branches of instrument repair enterprises in the outlying regions, and to establish mobile shops.

Under the leadership of local organs of the Committee, the control and revision work included the tasks of not only determining to what extent enterprises and organizations were observing standards and technical specifications in their production, or to expose shortcomings in the status of measurement techniques, but mainly to eliminate infractions and shortcomings on the spot.

The quality of the control and revision work has improved recently and its effectiveness has increased. There was also an improvement in the use of test materials.

During the second half of 1959, and first half of 1960, acting on the proposals of local organs of the Committee, the Councils of Ministers of the Union Republics, district "Ispolkoms", National Economic Councils and their managements, Republic Ministers and Departments as a result of the inspections issued over 400 decrees, decisions and orders directed toward the improvement of the quality of production articles.

However, main attention during inspections of the observance of standards and technical specifications was given to eliminating the exposed shortcomings directly on the spot, which in many cases leads to an increase in quality and decrease in production rejects, removal of obsolete articles from production, and an improvement in technological processes.

It is necessary to expand considerably the work carried on by the GKL (government control laboratories) in introducing new measurement techniques in the national economy, improving production quality, and regulating the status of measuring devices. To achieve this it is necessary to examine the volume of test work carried on by local organs of the Committee to determine the possibility of decreasing it in order that the workers thus made available could give their attention to the solution of problems relating to technical progress.

Local organs of the Committee must use every means for essential expansion of the systematic departmental and technical inspection not only of instruments in new fields of measurement but also of those which have long been used in the national economy.

It is necessary to raise the qualifications of GKL workers in order that they may render practical assistance to the national economy on all problems relating to measurement techniques. It is also necessary to expand the authority of the Councils of Ministers of the Union Republics and the GKL directors to give them increased powers and greater responsibility for rapid and high-quality solution of the problems which confront them.

RATIONALIZING TESTS — THE MOST URGENT PROBLEM FOR GOVERNMENT CONTROL LABORATORIES ON MEASUREMENT TECHNIQUES

B. L. Sokolov

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 3-4, December, 1960

The problems set forth by the 21st Congress of the KPSS (Communist Party of the Soviet Union) in the field of technical progress, viewed as decisive conditions for fulfillment of the 7-year plan, reveal wide opportunities for the growth of creative initiative of all the Soviet people. In achieving technical progress in the national economy, great significance is given to the development of inventions and rationalization.

The administration of the authorized Committee of the Council of Ministers of the RSFSR adopted organizational and technical measures to begin activities in the GKL (government control laboratories) on measurement techniques along these lines.

As a result, the workers of the government control laboratories of the RSFSR made 43 proposals in the 4th quarter of 1959 alone, and 69 for the whole year, regarding improved techniques. During the first 8 months of 1960, 50 proposals were registered and acted upon by the BRIZ Committee; nearly 100 proposals of local significance were examined in local BRIZ laboratories.

Successful work in the field of introducing and popularizing these proposals is being carried on in the laboratories of Voronezh, Gorky, Ivanov, Murmansk, Krasnodarsk, Kirov and other cities.

Of special interest are the proposals for testing single-phase phase meters, at 2,500 cps, for the UV-1 equipment (Mr. Obryadin, Chelyabinsk GKL), for testing stationary tachometers by using special attachments (Mr. Suvorov, Ivanov GKL), for a method of testing electronic frequency indicators (Mr. Taranenko, Kuibyshev GKL), for automatic regulation of furnace heat for testing thermocouples (Miss Ponomareva, Perm GKL), for testing the electrical resistance of instrument coils (Messrs. Bogdanov, Shavrinskii and Katkov, Murmansk GKL), for a portable machine for checking the accuracy of graduated lines on the balance arm of weighing scales (Mr. Libus', Ryazansk GKL).

A large number of proposals for improved techniques resulted in an increase in labor productivity of government testers. For example, a portable device developed by the Voronezh GKL for testing ac and dc ammeters and voltmeters by the comparison method increased labor productivity by 50%.

Modernization of the UPS-1 equipment for testing 3-phase meters, which was done by the Gorky GKL, resulted in a substantial saving of time required for making circuit connections for wattmeters, excluded the possibility of errors in connection and also the need for initial corrections of the circuit, etc.

A universal panel for testing single-phase electric meters, developed by this same GKL, permitted an increase in labor productivity of 5-6 times in connecting and disconnecting the meters under test, and their warm-up and testing under 100% load for creepage and sensitivity.

In order to achieve wide application of the approved proposals the administrative office of the authorized committee under the Council of Ministers of the RSFSR periodically informs all GKL of the devices, test equipment, etc., developed by the separate laboratories. During ten months of 1960, this office distributed to all GKL in the RSFSR six issues of such data containing descriptions, drawings, circuits and photographs of suitable portable measuring devices and equipment.

The informational material included, for example, descriptions and drawings of a compensating apparatus with a Class 2 laboratory potentiometer intended for testing platinum and copper industrial-type resistance thermometers for measuring temperatures from −200 to +500°C; potentiometric apparatus for testing secondary pyrometric instruments; potentiometric apparatus for testing liquid thermometers in a temperature interval of 300-500°C with a platinrhodium − platinum thermocouple, and 0-100°C using copper-constantan thermocouples.

Also worth noting is the description of an original bench stand for the UPN 3/2 equipment for annealing and welding thermocouples, and for heating the electric furnaces and supplying power, and the redesigned URP-4 equipment for testing radiation pyrometers. A well-designed high-capacity box makes it possible, during tests on the UM-2 and UM-3 and other universal bridges, to cover a capacitance range of 1-100 μf, which was unattainable previously.

The administrative office has issued instructions to all GKL to include in their quarterly and annual plans organizational and technical measures for installing approved proposals on new techniques, and as a result the GKL plans for using new measurement techniques contain measures for the realization of concrete proposals. By order of the administration of each GKL, authority was given to pay rewards to GKL workers for successful introduction of improved techniques, and also for proposals which are of local significance only. The workers of governmental and departmental inspection offices for measures and measuring instruments should continuously develop improved techniques and simplified test procedures, to reduce costs and testing time and to assure a high technical level of this work.

LINEAR MEASUREMENTS

A METHOD FOR DETERMINING ERRORS IN LINEAR MEASUREMENTS*

A. K. Kutai

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 5-9, December, 1960

The problem of determining errors in linear and angular measurements in machine building practice has recently received the attention of many metrologists. Three basic reasons may be listed in this connection: the need to hold errors in dimensions of a number of parts for machines, instruments and apparatus to ± (0.1-0.2)μ, and ± (0.2-0.5)μ for a larger class of parts; the production of measuring devices not only by specialized plants but also by many organizations for their own needs; and principally, new conditions which have arisen in measurement processes in connection with the mechanization and automation of controls, and the control of technological processes through measurement results.

*This article is a condensation of a report read in 1960 at the All-Union Conference at VNIIM (All-Union Scientific Research Institute of Metrology). Its format is a generalization of results obtained during consideration of the problem by the Interchangeability Committee of Leningrad Division of NTO (Scientific-Technical Department) Mashprom with the participation of several plants.

The selected method must provide two basic values in the determination: (a) error of the instrument, and (b) error in the method of measurement, by which it is understood the error includes the instrument error and error in the measuring method.

The permissible error (usually the instrument) and maximum error (usually the measuring method) are established.

If the terms set forth are easily recognizable, the additional terminology is far from uniform. Thus, for example, the value of the systematic part of the overall error in measurement is called the characteristic of measurement accuracy, whereas the value of the random part is called the characteristic of measurement precision. The latter term has a broader meaning and cannot be recognized as suitable for determining random error. In its place the term "reliability" is sometimes used, but this meaning is used for determining the capability of the instrument, stand, etc., to maintain normal operating qualities over a period.

A more suitable term is "uncertainty in measurement result", which is also adequate for mathematical representation of the random part of measurement error.

Even less clarity and singleness of meaning are found in such terms as instrument variation, total, over-all and supplementary error, etc.

It is thus completely obvious that it is necessary to standardize terminology even if only for a small number of the most useful and less generally known meanings. The definitions should be made up of algebraic symbols, and occasionally by formulas.

Error of the Instrument and Measuring Media. The method for determining the error of the instrument should facilitate the expression of the systematic error component and the random error portion.

The conditions for the determination, initially, are essentially different depending on the purposes of the determination. The plant producing the instrument will have one approach. But even here, depending on whether the instrument is in mass production, with all production problems solved, or whether the instrument has been redesigned, the method of determination will be completely different. In the first case, the determination must be made according to the rules governing the production method, whereas in the second, above all it is necessary to determine the theoretical instrument accuracy, specifying the error in circuit design and assembly, and then to calculate the total error including, in addition, the errors in production, adjustment and testing.

Since each unit of a mass produced instrument is a separate one of a group, its systematic error can be reviewed as a random one.

The second approach must be made during instrument operation. During the metrological testing or checking of an instrument, above all, it is necessary, to a maximum degree, to expose and eliminate the systematic errors.

By determining the measuring error in operation, the user can rightfully consider the permissible (nominal) error of the instrument as random. Under production conditions only a few corrections may be necessary for the purpose of eliminating readily apparent systematic errors. In the case of measurement media in automated processes or where they are connected directly into the technological circuit, the insertion of corrections, as a rule, is generally impossible.

It is obvious from the above that, depending on the conditions under which the metrological specification is established, its content will be different even for the same type of instrument. However, for a uniform approach in developing the specification, it is necessary to issue compulsory norms on the method for establishing the error of the measuring media for instruments in production as well as in operation.

In establishing the norms it is necessary to take into consideration a number of initial conditions:

1. It is necessary to differentiate between simple and complex errors. The latter consist of a combination of such simple errors as are most adequate for the objectives of measurements on a given instrument. In determining quality only the complex errors are considered important.

In calculating accuracy and setting up procedures for testing instruments, it is necessary to take into account the form and parameters of the material specimens which are to be measured (cylindrical and flat scales, spindles, thread gages, rack and pinion gears, worm gears and wheels, etc.). The geometric parameters of specimens of this type should conform with the limits of measurement and indication of the instruments.

2. In the norms it is necessary to establish the forms of systematic errors which cannot be excluded, and are determined by the testing procedures for instruments newly produced as well as those in operation.

Thus, the temperature error can be limited to the error in reading the thermometer apparatus and its inherent error, if we insert a correction for deviation from 20°C. We shall note, in passing, that the temperature error is perhaps one of the most essential since even in the thermally stable conditions in laboratories a deviation of ± (3-4)°C is not unusual.

3. It is necessary to set forth the instrument error by functions which take into consideration the geometric parameters as well as the physical and mechanical properties of the part being measured; the importance of the latter arises in connection with the expanded utilization of plastic substances.

The terms of the error formula are established with par. 2 taken into consideration.

The user, in determining the error in the measurement results, must be able to determine the part of the instrument error generated which can be applied to a concrete measurement objective.

The formulas on errors of precision instruments for linear and angular measurements, cited in the instructions, technical specifications and the pamphlets of instrument-producing plants, and in technical manuals, frequently are not in agreement with each other, and have not been subjected to reliable experimental verification.

4. A very real problem is presented in establishing a method for determining error in automated measuring media, including apparatus for active and regulating control, and also apparatus built into a machine with programmed control.

The characteristic traits of measurement equipment of this class take on a functional form of instrument error for a given series of measurements, where the duration of the measuring process is considered a variable. In establishing the overall functional error of the instrument, it is necessary to take into account not only temperature change, measuring force, number and type of contacts, but also specific errors — "zero drift" resulting from vibration, imbalance in the inertial mass and self-oscillation.

Finally, in automatic measurements, the instrument reading is sometimes made with the use of self-recorders which introduce their own inherent properties in establishing the permissible error of the measuring apparatus.

The determination of indeterminate zones due to random errors is discussed below.

Error of the Measuring Method. The selection of measuring medium and determination of error in the measuring method depend on the measurement problem. Two basic problems may be distinguished:

1. Measurements intended for expressing the accuracy of the measured object, arbitrary, exploratory, etc. These measurements are usually carried out on universal instruments. In such cases, the maximum error of the measurement result (or individual measurement) is determined by a universally adopted method.

Measurements of this type may be referred to as test measurements.

2. Measurements intended for adapting the parts to specialized measuring apparatus.

Instruments for special purposes fall in this category (for example, for complex testing of gears, camshafts, lead screws, turbine blades, etc.) with the assistance of control-measuring devices and means for active control and automation.

Measurements of this type may be called acceptance measurements.

The quality of the accepted parts and the maintenance of uniformity of measure depend on the determination of measurement error. Therefore, the creation of norms for establishing the method of determining maximum error in measurement and control is an important and imperative task.

Let us look into certain basic principles for working out methods of this type.

For acceptance measurements it is necessary to standardize the acceptance zone not only to a maximum error of measurement γ_{max}, which must comprise tolerance component δ (frequently, γ_{max} is taken as equal to 0.05-0.15 δ), but also its full range, taking into account the acceptance quality of the part under test. In using the terms of mathematical statistics, it is necessary, above all, to determine the permissible error of the 1st order (probability of rejecting acceptable parts) and of the 2nd order (probability of accepting unsuitable parts).

Without going into the details of this method, we shall simply note the absence of a single approach in those investigations which have been carried out and published in part. Let us examine two of the most significant works.

P. Leinweber [1], in connection with his development of proposals for setting up tolerances on gages for an ISO system, determined errors of the 1st and 2nd order (referred to by him as the risk of producer and consumer) on the following premises:

a) linear dimensions of parts are distributed according to Gauss' law where the mean arithmetical value corresponds with the coordinate center of the tolerance margin, and the accuracy of the production process is characterized by the mean quadratic deviation

$$\sigma_T = {}^1/_4\,\delta;\ \sigma_T = {}^1/_6\,\delta \text{ and}$$

b) the errors in measurement are also distributed according to Gauss' law and γ_{max} may be 0.05, 0.1 and 0.2 of δ.

In the results of the initial, tentative project on a tolerance system for ISO gages (published in 1959) proposals were made for establishing a relationship between the consumer's risk and producer's risk of 1:10 and 1:20 for operational control, which corresponds to a multiplier a equal to +0.5 and +1.0 in Formula (1) for determining the zone α for errors in the measured part, with the use of indicating (dial-type) measuring media.

Thus

$$\alpha = a\sigma. \qquad (1)$$

The calculations carried out by P. Leinweber are conditional to a large extent.

In our own as well as foreign investigations (USA, France) it turns out that, as a rule, the center of the empirical distribution does not coincide with the center of the tolerance margin; we established that the displacement ϵ of the centers, in normally flowing and quality processes, comprised a value of the order of 0.05-0.1 of the tolerance δ. Parts placed under test sometimes showed a dispersion somewhat greater than $^1/_4\,\delta$. Other departures from the premises accepted by P. Leinweber were also noted. For this reason the 1:10 and 1:20 ratios need verification.

The necessary requirements are met more adequately in the work carried out by B. A. Taits and N. N. Markov [2] in which they determined the errors of the 1st order (n), 2nd order (m) and maximum value (c) for the number of dimensions falling outside each tolerance limit when the error is m. Calculations were carried out to determine the concentration of part dimensions in distribution patterns according to the laws of Gauss or Maxwell. The technological dispersion was taken differently since, within the limits of δ, 3 to 6 σ_T can be inserted. From the resulting graphs the possible displacement ϵ may be calculated.

In the work of these two authors, the sequence shown for the zone of maximum error is opposite since Leinweber makes the following assumption: for the origin γ_{max} is taken as 0.35 (quality 1-4 according to ISO) and up to 0.10 (quality 11-16) of δ. Depending on the requirements for rigidity in acceptance, the field γ_{max} is placed in one form or another within the tolerance limits, which also changes the relationship between m and n. These authors come to the conclusion that in the overwhelming majority of cases the field of γ_{max} can be set beyond the tolerance limits, while, at the same time, P. Leinweber assumes that the zone α under working conditions nearly always is within the tolerance area; that is, he considers it necessary to separate the production tolerance.

In both of the works discussed above certain aspects of the problem have not been taken up. In machine building, for the most part, production processes are observed in which the distribution of the quality indices (dimensions, weight, etc.) does not follow the law of Gauss completely. In determining the error zones, it is essential to use the commonly observed deviation of experimental from theoretical frequencies in the tolerance limits, rather than the flat-topped curve which is used by P. Leinweber. The above deviations are produced in accordance with the regulations of process flow for the purpose of eliminating the appearance of rejects [3,4]. For this reason processes of this type are characterized as an instability, in time, of the statistical characteristic of distribution

[4], which is particularly important when the production processes are automated and control and acceptance are connected into the technological circuit. These circumstances make it imperative to find the maximum acceptance error (which, strictly speaking, is referred to as the error of the 2nd order) P_{bmax}. The method of finding P_{bmax} for the selection of a feedback system during automatic control (that is, for a somewhat different arrangement of the problem) is written up by the author in [5].

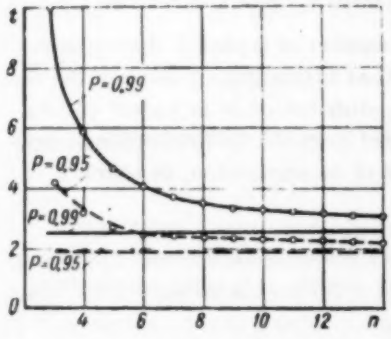
In the norms for acceptance measurements it is necessary, above all, to establish the values for errors of the 2nd order which have a direct influence on the quality of the parts considered acceptable. It is necessary to scale these values from the smallest (about 0.2%) to the largest still tolerable (about 2%).

The standard for statistical (selective) acceptance control must be adjusted, in regard to errors of the 2nd order, to the norms for the acceptance measurements. As far as the zone of measurement error and its distribution are concerned, these are related to errors of the 1st order. This side of the problem is decided from the technical-economic viewpoint. It may be stated that for the same value of errors of the 2nd order, depending on production conditions, it is expedient to take different values for errors of the 1st order.

A second important factor is the establishment, in the norms, of the most important components of the overall error γ_{max}.

We may add, as significant errors in the measurement procedure, the temperature error and contact error.

The latter errors are understood to be errors introduced by the measuring force, form and number of contacting surfaces, etc.*



In the ISO project mentioned above, the mean quadratic deviation (1) would be

$$\sigma = \sqrt{\left(\frac{Mu}{4}\right)^2 + (bD)^2 + (cT)^2}, \qquad (2)$$

where the constants b and c take into account the temperature and contact errors (the first term is the instrument error).

Of course, for different types of linear and angular measurements, other systematic errors must be taken into account even though, in most cases, they have a lower specific weight in γ_{max}.

Determination of Random Errors and Calculating Total Error. Let us deal only with direct measurements of equal accuracy, whose random errors are distributed according to Gauss' law.**

In any case, it is more essential to establish reliable limits for the measurement result than for a single measurement from this group.

It follows, unconditionally, that the norms should limit to a maximum degree the single-type readings. In taking down only one reading, the information on the actual dimension of the part is completely insufficient, and it is impossible to determine reliable limits. As a rule, the number of readings n during the test measurements should not be less than 2 or 3, and for critical and arbitrary measurements $n \geq 5$-7. For certifying instruments the limit should be n = 9-10. As is well-known, the indeterminate zone in the measurement result decreases in proportion to $\sqrt{n}$.

In checking and certifying precision instruments, it is a good policy to carry out part of the multiple measurements with repeated set-ups on standard measures or parts.

* They are considered random since, here, we have not provided a definite measurement objective; in the opposite case, they would preserve the traits of the systematic errors.

** Other distributions are infrequently encountered; in accordance with Simpson's law of near-equal probability, or asymmetrical, as, for example, for automatically occurring measurements or measurement of small apertures.

Depending on the accuracy, complexity and extent of the part, it is advisable to take measurements at different cross sections of the same nominal surface. In the ISO document cited above, it was suggested that the smooth cylindrical gages be measured at 9 points, with the mean value taken as the reading.

To some extent, the above also applies to acceptance measurements. A high assurance to the consumer against his receiving unsuitable parts leads to a significant number of rejects of suitable parts due to errors of the 1st order. Therefore, even with automatic processes of control and measurement, rejected parts are re-tested in practice.

As is known, the indeterminate zone in the measurement result $\bar{X}$ is represented in the following form:

$$\bar{X} - t\sigma_{\bar{X}} < \bar{X}_0 < \bar{X} + t\sigma_{\bar{X}}, \tag{3}$$

where $\bar{X}_0$ is the real value of the measured quantity; t is the parameter determined by the distribution law and level of probability,

$$\sigma_{\bar{X}} = \frac{s}{\sqrt{n}}, \tag{4}$$

where s is the mean quadratic deviation found from a series of observations n.

Historically, a so-called classical method for determining maximum error in linear measurements was established, where $t = 3$, which corresponds to a probability level of 0.9973, assuming a Gauss distribution.

A determination of this type which would still be tolerable with a large number of repeated observations ($n \geq 30$) does not conform with modern theoretical ideas and gives an under-valued indeterminate zone in the case of small n. It is more correct to establish reliable limits (intervals) using the t_0-distribution of St'yudent [6]. As can be seen from the curves (see the figure), the value of t of Formula (3) found from the t_0-distribution increases as n decreases; the lines in this same graph relate to the "classical" method of determination, in which n is assumed to be large. The data presents two levels of probability P.

It is time to reject in all cases the use of $P = 0.9973$. If it is justifiable, in determining instrument error, to use $P = 0.98$ or 0.99, then, in establishing reliable limits for the measurement results, it is quite permissible, as a rule, to take $P = 0.95$.*

In totaling the errors for determining the calculation accuracy of an instrument under design, a quadratic summation by a formula similar to (2) is universally used for determining the permissible error of the instrument or the maximum error of the measuring method, which includes the instrument. In this procedure, individual errors are taken as maximum ones and the nature of their distribution is not considered; the total mean quadratic deviation is calculated on the basis of the overall method of multiplication by 3 or 2.

Naturally, such calculations will lead to confined values. In order to avoid the use of arbitrary calculations, the standards and technical specifications for the instruments should include the value "s permissible" as well as "γ permissible".

If the individual error is a small remainder of a non-excludable systematic error, then a quadratic summation is plausible. However, if an error of this type is a systematic one, besides not being maximum, then it should be summated algebraically. A different approach to this problem depends on whether the summation of errors can be found for a series of instruments in production, or whether this total error characterizes a series of measurements carried out on a single instrument, etc.

The determination of total error in acceptance measurements and the set-up itself become quite complicated in cases involving automatic measuring methods or when they are part of the technological circuit. The error in these cases is divided into an initial, or adjustable one and error in the process flow; the latter depends on the duration of the measurement process and may be represented as a random function.

* In calculating the indeterminate zone in the ISO project, $P = 0.9545$ and $t = 2$.

Judging from the few investigations carried out in the USSR and abroad, the process-flow error depends not only on the usual factors taken into account (temperature, measuring force, etc.), but also on specific factors including elastic deformation of the technological circuit and elements of the measuring set-up, the influence of fluctuations in allowances made during the manufacture of the article, the influence of regulating or self-adjusting measuring devices, rapidity of set-up connections, or changes in conditions due to feedback, etc.

Future work should establish guide-lines and then take up the coordinated development of the methodology for determining instrument errors.

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V-SHAPED COMPENSATOR FOR THE LINNIK MICROINTERFEROMETER

A. I. Kartashev

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The Linnik microinterferometer, which has received wide application, permits the study of surfaces which have irregularities of specific form and depth. Interferograms obtained with this instrument are easily deciphered if the surface has consistent irregularities of a directional character, and a depth not exceeding a few microns (2-3μ), that is, if it is possible to detect distortion of the interference bands of any order. Usually the measurements are carried out at zero order, using white light. However, the use of white light can lead to errors of one or several orders when determining significant depths of irregularities, particularly those of a step nature. Frequently, the measurement by microinterferometer of irregularities exceeding 4μ becomes generally impossible.

The proposed V-shaped compensator, in the form of an attachment to the microinterferometer, makes it possible, while preserving many of the advantages of the latter, to expand the measurement range to 30-40μ, particularly for surfaces of regular profile. The operating principle of this device is based on the compensation of the diversity in path of the light rays reflected from different parts of the surface at various depths, using the compensating wedge. As is known, the interferometer pattern in the visual field of the instrument in white light can be observed only in those places where the difference in the paths of the interfering rays is not large.

If the depth of the irregularities is quite large, then it is possible to observe, in the eyepiece, interference either from the ridges or valleys on the surface. The absolute measurement of the distance between the ridges and valleys, that is, the determination of the depth of the irregularities, becomes possible if we compensate for the differences in path. Figure 1 shows the optical arrangement of the Linnik microinterferometer with the V-shaped compensator.

Let us assume that the object of measurement is represented as a step of depth H. The value of H is sufficiently large so that the interference bands in white light can be observed only on one single surface at a time, and either the step or the microscope is moved sequentially along the optical axis. Let us assume that the step is located so that the paths of the rays a and a' are equal. Then, we see, in the eyepiece, interference bands on

the left face of the step. Onthe right side, the difference in path of the rays b and b' is equal to 2H and interference is not observed. If we insert a wedge in the plane of the output lens of the system (beyond the eyepiece), then the light which is reflected from its surface undergoes further reflections. For the case when the value of the air gap is equal to the depth H, interference bands superimposed on the white light will also be seen on the left part of the stepped surface, since the difference in paths between rays b and b' is equalized. Knowing the angle of the wedge α, and measuring the value l, we can then compute the depths of the step from $H = l \operatorname{tg}\alpha$.

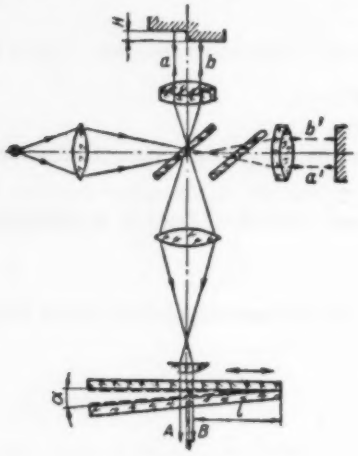
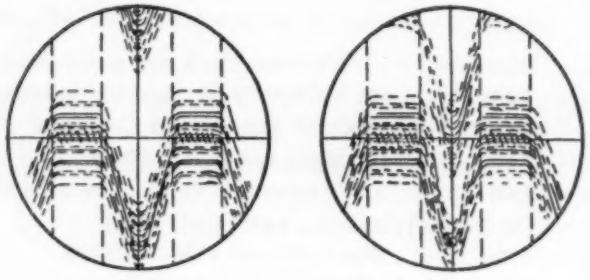


Fig. 1.



a b

Fig. 2.

The compensator may be constructed in the form of an interference wedge made up of two flat glass plates with light-separating layers of silver, and separated by a V-shaped air gap. When such a wedge is inserted in the plane of either the input or output lens of the optical system of an interferometer microscope, bands will appear in the visual field, superimposed on the white light in each case when the difference in paths produced by the presence of irregularities on the surface under study is equal to the width of the air gap of the wedge at the given point. By shifting the wedge in a direction perpendicular to the optical axis of the microscope system, it is possible to compensate for the various differences in path in relationship to the wedge constant and the value of the difference being measured.

The high reflection factor of the light-dividing layers of the wedge (0.90-0.95) makes it possible to obtain sufficiently contrasting interference bands of the first order during observations of the patterns in white light. The V-shaped compensator may be built into the interferometer system in such a way that it can be removed completely. When the wedge is removed, bands of zero order only, from either the crests or the valleys on the studied surface,will be observed in the visual field of the interferometer. By lining up the thread markings of the eyepiece with the black achromatic band and inserting the wedge gradually, we will observe in the visual field precisely the kind of secondary system of interference bands which will result in superimposition of the beam of rays in each case when the difference in path produced by the presence of irregularities on the radiated surface is equal to the width of the air gap in the wedge. By gradually shifting the wedge, both systems of interference bands may be brought together. The coincidence of the achromatic bands of zero and first order will correspond to the equality of wedge width and depth of the micro-irregularities. By a simple reading on the barrel of the eyepiece micrometer of the compensator, it is possible, with a corresponding graduation of the wedge, to obtain the values for the depth of the micro-irregularities. This compensator makes it possible to expand the application range of an interferometer microscope to cover the certification of standard samples of regular profile to Class 4 surface fineness and to reduce certification error to 3-5%.

Figure 2 shows a view of the visual field of the microinterferometer when measuring the depth of the grooved irregularities on a roughness specimen of regular profile. In case a, only one system of bands is seen; in case b, the difference in path has been compensated for and we may observe, opposite the black achromatic bands of the ridges, a second system of bands with a black achromatic band at the valleys.

The compensator is constructed in the form of a small fitting easily attached to the eyepiece of the MII-4 microinterferometer.

For successful application of the compensator and to make possible the observation of sufficiently sharp interference bands, it is necessary to decrease to the limit the aperture diaphragm of the microscope. Using the described compensator, measurements of specimens of regular profile were carried out by different observers, with various arrangements on the instrument, and with different values of irregularity depth and different groove shape. The results of the measurements showed that the different observers who used the compensator and measured irregularity depths of 3 to 17 microns, corresponding to classes 8-5 of surface roughness according to GOST 2789-59 (All-Union State Standard), differ in their average readings from observations at nine points on the specimen by not more than 2.7%. In addition, it should be taken into account that these measurements correspond to a single reading for each section, and we cannot exclude the possibility of the effect of irregularities in the specimen itself on the average values.

By comparing the results obtained with the compensator to the results of measuring these same depths of irregularity at the same points by enumerating the whole and partial number of bands in monochromatic light, it was shown that the divergence at the individual points did not exceed 0.19 microns, and the mean values differed by not more than 0.04 microns. Thus, the Linnik microinterferometer, equipped with a compensator, makes possible the measurement of substantial depths of irregularities with sufficiently high accuracy.

THE USE OF PNEUMOELECTRICAL MEASURING UNITS IN THE TRANSIENT STATE

A. P. Kurochkin and F. V. Tsidulko

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A certain slowness of response is an inherent property of pneumoelectrical measuring devices and it restricts their use in automatic inspection and sorting machines.

There are two ways of increasing the productivity of pneumoelectrical measuring units: a) reduction of the operating time by, for example, mechanical cutout of the measuring chamber for the entire period when there is no component on the measuring station, and b) the so-called "dynamical" use of measuring elements, i.e., their use in the transient condition.

The measuring equipment and measuring elements for operating on the first-mentioned principle are complex in design.

In the second method the inspection must be carried out in the short period of time before the moving parts of the measuring unit have reached the state of equilibrium, i.e., in the transient state. This obviates the need for reducing the measuring unit's time of operation, and eliminates all difficulties involved; it also opens possibilities for reducing the time available for performing the measurement.

In the following we describe the results of our metrological investigation of this method, carried out at the Bureau of Interchangeability on bellows and membrane-type detecting elements; the tests took into account a large number of parameters of the system.

Figure 1 shows as an example some of the experimental curves illustrating the time dependence of the motions of bellows detecting elements. The point A of these curves represents the total time of operation t_{op} of the pneumatic system with nominal measuring clearance; later the measuring clearance was gradually reduced and the time of operation determined for each of these S values.

The fact that the functions shown in Fig. 1 are unambiguous makes the principle of the method clear; the ordinate of the point A, representing the dimension after equilibrium has been attained, can be determined from the ordinate of the point B corresponding to a transient state.

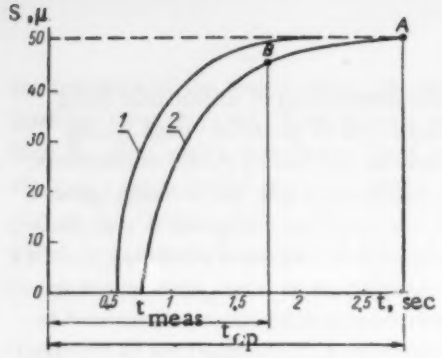

Fig. 1. At $d_v = 0.80$ mm, $d_i = 2$ mm, S = = 0.050 mm; curve 1 for H = 1 kg/ cm^2; curve 2 for H = 2 kg/cm^2.

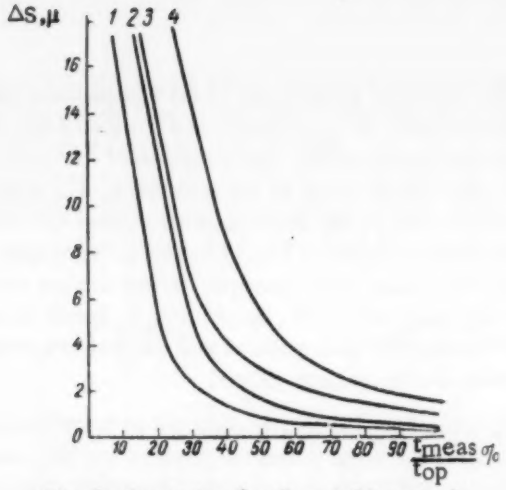

Fig. 2. Curve 1 – for d_v = 0.80 mm, d_i = 2 mm, H = 1 kg-wt/cm^2, S = 0.050 mm; curve 2 – for d_v = 1.20 mm, d_i = 2 mm, H = 2 kg-wt/cm^2, S = 0.180 mm; curve 3 – for d_v = 1.60 mm, d_i = 2 mm, H = 1 kg-wt/cm^2, S = 0.200 mm; curve 4 – for d_v = 2.20 mm, d_i = 2 mm, H = 2 kg-wt/ /cm^2, S = 0.400 mm.

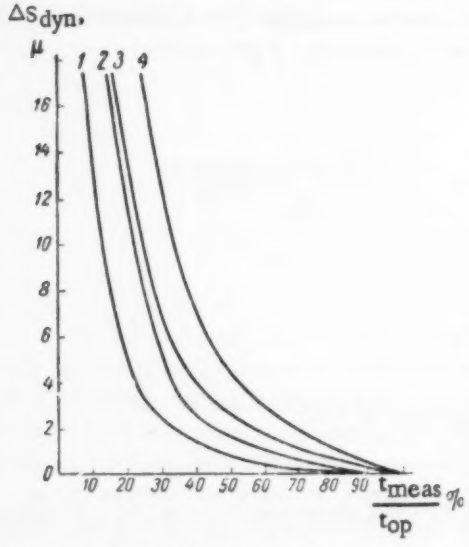

Fig. 3. Curve 1-for d_v = 0.80 mm, d_i = 2 mm, H = 1 kg/cm^2, S = 0.050 mm; curve 2-for d_v = 1.20 mm, d_i = 2 mm, H = 2 kg/cm^2, S = 0.180 mm; curve 3-for d_v = = 1.60 mm, d_i = 2 mm, H = 1 kg/cm^2, S = 0.200 mm; curve 4-for d_v = 2.20 mm, d_i = 2 mm, H = 2 kg/cm^2, S = 0.400 mm.

However, the dynamic use of the measuring units introduces a dynamic error – in addition to the ordinary (static) error – which is due mainly to the instability of the time t_{meas}.

A special apparatus was made for determining the size of errors; it made possible the fixing of the time t_{meas} by means of an electronic time relay. In order to improve the accuracy of this relay the voltage was stabilized by means of an SMÉ-120-0.1 ferro-resonance stabilizer. The actual magnitude of t_{meas} was determined by means of a PV-53L electric stop clock with 0.01-sec divisions.

Figure 2 shows some of the curves obtained. Here the abscissas represent t_{meas}/t_{op} in %, and the ordinates the total experimentally determined measurement error in μ. All curves are similar in shape regardless of the pneumatic system's parameters. The ordinates of the point t_{meas}/t_{op} = 100% yields the static error; at t_{meas}/t_{op} < 100% the curves give the total error, which is the result of the combined static and dynamic errors. To determine the dynamic error from these curves it is necessary to know the laws governing the distribution of errors. In our tests the static error obeyed the law of normal distribution. The dynamic error is normally the result of an incorrect fixing of time t_{meas} due to variations in operating time of the time relay, and its distribution also obeys the normal law. Thus, it can be assumed that the dynamic error, too, follows the normal law of error distribution. Figure 3 gives the curves of dynamic errors obtained by subsequent mathematical processing on this assumption, from the curves of Fig. 2.

An examination of this family of curves (some are shown in Fig. 3) leads to the conclusion that the actual error of the dynamic inspection method is generally caused by the error in fixing (maintaining) the time of measurement t_{meas}. We determined from curves of the type illustrated in Fig. 1 the errors due to the inaccurate operation of the time relay, by multiplying the error of the relay (which was 0.025 sec) by the derivative of the curve concerned at the corresponding point. The data thus obtained showed a good agreement with the values of errors taken from the curves of Fig. 3.

Using the curves of Fig. 3 and a number of other similar curves obtained in various operating conditions, a table was compiled containing the results of the metrological testing of the dynamic method over a wide range

d_1, mm	d_v, mm	H, kg/cm²	Linear section of the characteristic,	t_{op}, sec	Permissible relative error, %								
					3			5			10		
					ΔS_{dyn}, sec	$\frac{t_{meas}}{t_{op}}$, %	t_{meas}, sec	ΔS_{dyn}, sec	$\frac{t_{meas}}{t_{op}}$, %	t_{meas}, sec	ΔS_{dyn}, sec	$\frac{t_{meas}}{t_{op}}$, %	t_{meas}, sec
1.5	0.55	1	35	3.5	1	50	1.8	1.8	40	1.4	3.5	25	0.9
		1.5		5.0			2.5			2.0			1.3
	0.80	1	70	2	2.1	44	0.9	3.5	35	0.7	7	23	0.5
		1.5		2.5			1.1			0.9			0.6
	1.20	1	40	2.7	1.2	42	1.1	2	33	0.9	4	24	0.65
		2		2.9			1.2			1.0			0.7
2.0	1.20	1	70	1.1	2.1	44	0.5	3.5	34	0.35	7	26	0.3
		1.5		1.4			0.6			0.45			0.35
		2		1.5			0.65			0.5			0.4
	1.60	1	120	1.0	3.6	43	0.45	6	33	0.35	12	23	0.25
		2		1.2			0.55			0.4			0.3
	2.20		300	0.7	9	38	0.3	15	28	0.2	30	20	0.15

of application of pneumoelectrical measuring units. The table is compiled as follows. For each combination of parameters of the pneumatic system we determined, knowing the length of the linear section (of the curve) of the characteristic curve, for the permissible values of the relative dynamic error of 3, 5, and 10% the permissible dynamic error of measurement ΔS_{dyn} (in the case the relative error means the ratio of the measurement error to the length of the linear section of the curve). Next we found for the curve for the given operating conditions the corresponding value of t_{meas}/t_{op}%; for the known t_{op}, this gave us the value of t_{meas}.

By means of this table it is possible to find the dynamic measurement error caused by a definite reduction of the time normally required for measurement. The converse problem can also be solved: for any permissible dynamic error can be found the minimum time required for taking a measurement.

The close agreement of the data in each of the columns t_{meas}/t_{op}% indicates that for the same values of the relative gain in time the values of the relative dynamic error are independent of the parameters of the pneumatic system.

On the basis of the above considerations and the data of the table the following recommendations can be made on the range of applicability of the dynamic measurement method with pneumoelectrical measuring units: for any parameters of the system the time allocated for a measurement can be reduced to 2/3-1/2 of the operating time.

Tests showed that the only difference between the dynamically used bellows detecting elements and the membrane-type detecting elements used in the same way is that the error of the membrane instruments is slightly lower. This can be explained by the fact that, owing to their simpler design, the stability of the elastic characteristic of the moving parts of a membrane-type measuring unit is better than the stability of the corresponding characteristic of a bellows-type unit. However, the difference in the magnitude of errors of both types of instruments is very small, and this represents an indirect proof of the fact that the stability of the elastic characteristic of the moving parts is not the main source of its dynamical error. In the case of the membrane-type device the data of the table apply when the error measured is reduced by 10%.

If it is intended to modify an existing static automatic inspection machine for dynamic operation, or a machine being designed, it is useful to know that a time relay is not always needed; quite often it is sufficient simply to increase the speed of the machine. Operation without a time relay is based on the utilization of the mechanism of the machine for fixing the inspection time t_{meas}. The accuracy achievable depends on the type of kinematic linkage used in the machine. The possibility of the use of the machine without a time relay depends on the desired t_{meas} value and the permissible error and also on the type of mechanism used in the machine. Special tests were carried out at the First State Ball Bearing Factory to investigate the operation of mechanisms of various machines for the inspection of ball and roller bearing races. These tests showed that the errors in fixing the inspection time by the mechanisms of the machines themselves do not exceed 0.05 sec. Thus, in these

machines the time needed for the measurement can be reduced to $^2/_3$ and often even to $^1/_2$ of the original time without the use of a time relay; this method is actually being used on an automatic machine for the inspection of automobile pistons.

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MEASUREMENTS OF TIME

A NEW DEVICE FOR THE RECORDING AND SUMMATION OF PERIODS OF TIME

A. G. Fleer

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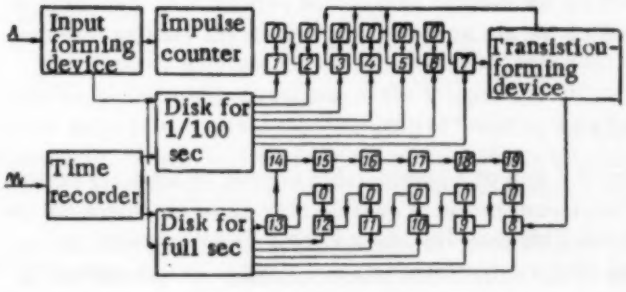
In determining astronomical time, observing artificial satellites, comparing frequencies, etc., the need often arises of calculating a mean of a considerable number of individual periods of time recorded by means of a time measuring device. The main instrument used at present for this purpose is the printing chronometer clock. The diagrams plotted by this instrument are decoded, entered in the observation book, totalled and the result is divided by the number of recorded periods. The results so obtained are later compared with the indications of the clock. All these operations require considerable time. For example, in processing chronograms of a single 12-star astronomic correction of the clock taken by means of an APM-10 instrument it is necessary to determine the average of 650 four-figure numbers. Four to five such corrections are normally observed in one evening. All this renders the problem of a partial or complete automation of the process very important.

At the 6th International Conference on Chronometry (1959) a paper on an instrument developed by Blase (Switzerland) was presented; with this instrument it is possible to obtain an average of 20 recorded time impulses.

In the same year an instrument was developed and built at the Laboratory of Time and Frequency of the Novosibirsk State Institute of Measures and Measuring Devices, which we named the computing chronoscope. This device combines the properties of a chronoscope and the electronic computer necessary to produce the desired result. With this instrument it is possible to record a number of periods of time, to find their sum and to determine the number of recordings.

A block diagram of the device is shown in the figure.



The time is recorded by a synchronous motor whose rotation is transformed to 1 rps by means of a reduction gear.

The coding device consists in essence of two disks: a disk for hundredths of a second and a disk for whole seconds. Figures from 00 to 99 are marked on the first disk by alternate conductive and non-conductive sectors; the disk performs one complete revolution in a second. The second disk carries figures from 00 to 59, also on conductive and non-conductive elements. It moves discretely by 1/60 of a revolution in a second, thus completing the cycle in one minute.

The starting impulse operates the input single flip-flop oscillator, whose impulse is differentiated and passed through the cathode repeater to the disks of the coding unit. At the moment when the impulse being recorded appears the sliding contacts take from the disk the corresponding coded signal, which unambiguously defines the angular position of the disks at the moment in question. This signal, indicating the second and its hundredths, is passed into the parallel electronic computer.

According to the number of discharges being summed, the electronic computer consists of 13 identical trigger cells, with grid connections which are based on double triodes (1-13). In order to separate the parallel impulses

fed by the coding disks and the subsequent impulses of transmission from charge which appears as a result of summation, the single flip-flop oscillators (O) are introduced between the triggers. The length of the oscillators' impulses is selected in such a manner as to utilize their rear section for changing the condition of the subsequent trigger cell, in order to exclude the possibility of overlapping parallel pulses. The capacity reserve of the chronoscope is formed by 6 triggers (14-19) operating in succession, without intermediate kipp oscillators. Since the coding disk for the hundredths of a second is divided into a hundred sections, which does not correspond to the transmission of a single transfer impulse into the counting system of whole seconds, our circuit continues to accumulate the hundredths of a second up to 128. The single impulse of an oscillator of the transition-forming device thus formed is simultaneously passed through the cathode repeater into the second-section of the computer and onto the third, fourth, and fifth triggers of the hundredths-of-a-second-section, which restores the 28 units.

In addition, the device incorporates a circuit for minute counting.

The device is based on 6N2P tubes. An SB-1m/100 impulse counter is used for counting the number of recordings. The condition of the summing trigger cells is indicated by MN-3 neon signal lamps installed in the device; they give the total count in a binary system. Standard circuits have been used for the triggers and the single flip-flop oscillators.

The maximum capacity of the instrument is 4096.28 seconds and it can, on the average, record and total 120 periods of time. The maximum frequency of recording is 100 cps. The error of the final result is ±0.01 second.

The device is connected to a 127-220 v ac supply of industrial frequency. The synchronous motor of the time measuring device is connected to an ac supply of 100 cps, 140 v produced by a quartz reference generator or a 22P quartz generator. The power consumption from the ac main is 100 w and from the quartz generator amplifier 14 w. The device is operated by a positive impulse of 6-8 v.

The computing chronoscope was tested by comparing the differences of an average of 10 recorded time intervals, and the periods of contact of a quartz clock, obtained by means of an ÉChL printing chronograph and the computing chronoscope.

The differences "chronoscope minus chronograph" never exceeded ±0.01 sec, indicate a good agreement of results, and show that the instruments are completely interchangeable if the recording of minutes is not required.

We are at present engaged in the development of an electronic coding device which will replace the mechanical unit; it is based on the counting of impulses of a standard frequency by means of a binary counter and involves the use of a "witness" triode to indicate the condition of the trigger cell. The binary output of the device will in future make possible the division of the sum by the number of recorded periods, i.e., obtaining an average of the recorded periods. Another problem with which we are at present engaged is the feeding into the device of a definite problem for testing purposes.

SUMMARY

The described device makes it possible to determine the sum of a considerable number of arbitrary periods of time and to record the number of these periods. The instrument makes it considerably easier to determine the second and its hundredths by reducing the time needed for calculations. In addition, the computing chronoscope, whose output is binary, can form a basis for the automation of the calculation processes which are carried out in determining time.

From the Editorial Board

The use of the instrument described by A. G. Fleer is restricted by its inadequate accuracy in calculating the mean (0.01 sec). In the case of a missed or a false signal recording the sum will become incorrect, and the results of observing a star become useless.

Despite these shortcomings the device can of course be used in applications for which its accuracy is adequate.

THERMOTECHNICAL MEASUREMENTS

CALIBRATION OF RARE-METAL THERMOCOUPLES AGAINST THE MELTING POINT OF PALLADIUM

B. K. Bragin
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The increased demand for accurate measurement of high temperatures by the contact method resulted in the development of new thermocouples made of various platinum and rhodium alloys. Alongside with platinrhodium – platinum thermocouples of normal composition new elements are increasingly being used for important applications, and they must be calibrated with an increased accuracy. The calibration of a thermocouple by comparing it with a reference thermocouple is reliable only below 1200°C; the results thus obtained are used for a graphical or analytical extrapolation of the thermo-emf into the region of higher temperatures. It is normally based on a range of at least 400°C, which makes extrapolation into a higher region very unreliable [1].

By using accurate standard calibration tables the error can be reduced to ±3°C at 1600°C [2]; however, such tables, which are in need of further improvement, are available only for the frequently used platinrhodium – platinum thermocouples of normal composition conforming to GOST 3044-45.

The calibration error of rare-metal thermocouples, especially those of a new type, can be extended to the temperature region beyond 1200°C by an additional measurement of thermo-emf for a point close to 1500-1600°C. In this region, which is of particular interest to metallurgists, the melting point of palladium (1552°C) is the only reliable reference point.

The utilization of this point by the classical "crucible" method requires a considerable amount of metal (up to about 1 kg) and is very labor-consuming; it is therefore not used in the calibration of thermocouples. The latest calibration method developed at the D. I. Mendeleev All-Union Scientific-Research Institute of Metrology (VNIIM) requires less metal (500 g) and less time; with this method a calibration accuracy of the order of ±4.5°C can be achieved.

This method involves the use of a high-frequency furnace and of a first-class optical reference pyrometer for performing periodic measurements of the temperature of the solidifying palladium; it can therefore be used only in a few large laboratories. The methods of "melting wire" and of melting small samples on the junction of the thermocouple being calibrated have not been widely adopted although the equipment they require is simple. This is due, apparently, to the earlier difficulties encountered in obtaining pure palladium.

The "melting wire" method calls for higher skill and greater thoroughness in the preparation of thermocouples for calibration and in carrying out the relatively accurate tests involving the melting of palladium wire welded between the electrodes of the thermocouple. If the measurements are carried out correctly the scatter of results obtained by this method can be as low as 2°C.

Very little information is available on the method of melting small samples of metal on the junction of the thermocouple; it is entirely inadequate for assessing the method fully and adopting it for use in laboratories.

Our investigations showed that with regard to simplicity, efficiency, cost, and the reproducibility of results, this method is the most rational for the calibration of thermocouples with palladium. Because the thermocouples need not be placed entirely into the furnace for calibration the method is very convenient for use in periodic checking of thermocouples used in measuring high temperatures near the surface.

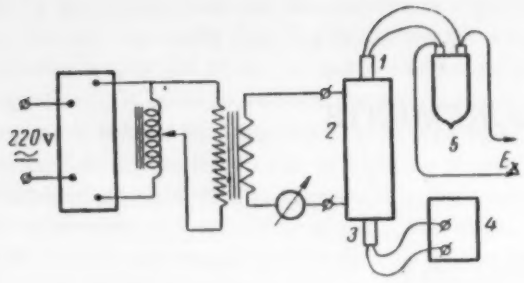


Fig. 1.

Apparatus

The apparatus which we recommend for use in the calibration of thermocouples at the melting point of palladium is illustrated in Fig. 1. For melting palladium samples on the working junction of the thermocouple 1 we use the vertical tubular resistance furnace 2, which has a double heating element of a platinum alloy containing 20% rhodium, in the form of 0.5 mm diameter wire. The inner heating element (R = 2.2 ohms) is wound on a 7 mm bore, 130 mm long, aluminum oxide tube. The tube of the external heater (R = 3.5 ohms) is made of the same material and its bore is 25 mm and length 150 mm. The pitch of the winding is uniform. Both elements have a refractory coating made of alumina containing 15% (by weight) kaolin. A 15 mm thick asbestos layer applied to the coating of the outer heater is used as thermal lagging.

With both heater windings connected in parallel and a current of about 9 amp the temperature in the central part of the furnace becomes stabilized near 1565°C. Initial heating time of the furnace, at a current of 10 amp, is 1 hour. The maximum power consumption of the furnace is 0.5 kw.

The temperature in the center of the furnace is measured by means of an ordinary platinrhodium – platinum (or a PR type) thermocouple 3, whose junction is protected by a solid high-alumina tube 70 mm long. The portable potentiometer 4 can be used as a secondary device for this thermocouple.

The furnace is mounted in a vertical position on a stand whose upper part has clamps for fixing the thermocouple being calibrated and a 0.25 liter capacity Dewar flask 5 containing melting ice.

The design and main parameters of the furnace can be slightly different [3] from those given here, but in any case a careful study of its behavior during the heating, and at the constant temperature of 10-15°C above the melting point of palladium, is necessary.

The thermo-emf E_x of the thermocouple being calibrated is measured by the compensation method with a low-ohmic laboratory potentiometer (KL-48, PPTN-1, etc.) with an accuracy of ±1 μv. UK units of the "Etalon" Plant are very useful in this work; they are used in many industrial and state weights and measures laboratories.

Palladium

The diameter of the palladium wire used in our tests was 0.4 mm and length 15 mm; it contained 99.95% Pd. A wire of this size can easily be placed close to the working section of the thermocouple being calibrated. If the wire is hard it must be annealed for a few seconds in a furnace at 1100-1200°C.

Henning gives [4] a number of experimentally obtained values for the melting point of palladium. According to the International Convention on the Temperature Scale (1948), the most likely value of the melting point of palladium is 1552 ± 2°C. Such accuracy in determining the melting point of palladium samples cannot be obtained in an ordinary laboratory which does not possess an optical reference pyrometer.

We have been able to calibrate three platinrhodium – platinum thermocouples at 1552°C by means of a VNIIM optical reference pyrometer, and thereupon to repeat the calibration 10 times by the method of melting palladium samples on the junction. The differences in the values obtained by these quite independent methods were smaller than the error of the optical reference pyrometer, which is ± 1.5°C near the melting point of palladium.

Thus, palladium containing not over 0.05% impurities can be used in the calibration of ordinary thermocouples. The melting point of this metal can be assumed to be 1552°C with an accuracy of ± 2°C. The obtaining of palladium of such purity presents no particular refining difficulties. The consumption of palladium wire for the calibration of 100 thermocouples was only 3-4 g, and the total loss caused by burning, etc., is negligible.

Thermocouples and Their Calibration

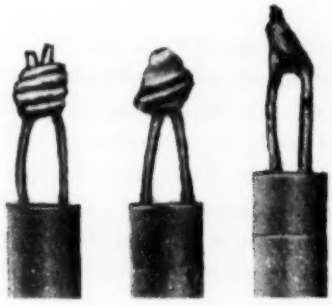
Our tests were concerned with the calibration of 3 platinrhodium–platinum, and 3 platinrhodium–platinrhodium thermocouples.

The working junction of the thermocouple was protected over a length of 70-100 mm by 4-5 mm diameter double bore tubes of aluminum oxide containing about 1% TiO_2. The thermocouples were supplied in an annealed condition but we subjected them to an additional annealing in a furnace at 1100°C for 1 hour, in order to remove any stresses produced during the introduction of the junctions into the tubes.

The junction of the thermocouple being tested was tightly tied with a 15-30 mm length of palladium wire, producing a compact 2-layer winding consisting of 4-5 turns. In some tens of tests we showed that the tight tying of electrodes can fully replace their welding. The tied end of the thermocouple must be pulled 10-12 mm out of the protecting tube and the electrodes pushed slightly apart to prevent their slipping back into the tube.

The working ends of thermocouples thus prepared for calibration are shown in Fig. 2a and 2b.

The thermocouple being investigated was placed into the furnace as soon as the temperature of the latter became stabilized at a level 10-15°C above the melting point of palladium. The free ends were held at a constant temperature of 0°C. When in the furnace the thermocouple must be well centered, while its junction must be located 5-10 mm above the junction of the reference thermocouple. In our tests a 70 mm length of the thermocouple was placed into the furnace.



a b c

Fig. 2.

Within a few minutes the working end of the thermocouple reaches the temperature of the melting point of palladium; during this process the initially very high heating rate is gradually reduced to 1-2°C per minute. The beginning of melting of the sample is indicated by 1-2 light oscillations of the zero-galvanometer indicator over 1-2 μv of the scale, whereupon the temperature remains stable for 10-15 sec followed by a slight increase of temperature by a few tenths of a degree. After melting, a sharp increase of the temperature of the junction is observed at a rate of several degrees per minute. Thereupon the heating rate falls again.

In our tests the time needed for a complete melting of the sample varied from 30 sec to several minutes. It depends above all on the degree of overheating of the furnace prior to the test. The average duration of melting of a 20 mm long and 0.4 mm diameter specimen was 60 sec. This proved entirely adequate for taking several readings of thermo-emf. A typical curve of the process of heating when melting a sample on the junction of one of the calibrated thermocouples is shown in Fig. 3.

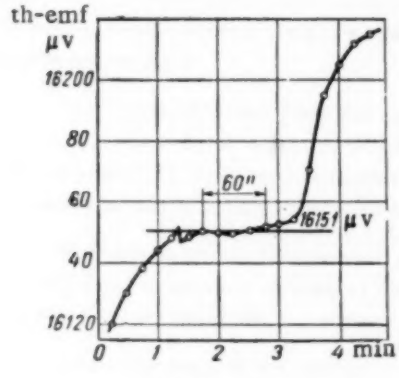


Fig. 3.

Two-three minutes after the completion of welding we compared the thermo-emf of the thermocouple being calibrated with that of the reference thermocouple. This proved adequate for producing a value of the reference thermocouple and for providing a picture of its variation during the process. After the completion of these measurements the thermocouple being calibrated was removed from the furnace, cooled, and its junction together with the melted palladium cut off. Figure 2c shows the working end of a thermocouple after the calibration.

The mean square error characterizing the reproducibility of calibration results for five tested thermocouples was not more than ±2 μv and only in one case was it 6.6 μv which, apparently, was due to an inadequate annealing of the thermocouple rather than the failure of the method. The method of small palladium samples on the working junction of a thermocouple introduces no appreciable systematic error into the results obtained. This is indicated by the good agreement of results obtained by the direct calibration of thermocouples against the melting point of palladium and the results obtained by means of the optical reference pyrometer.

One laboratory assistant can carry out in 8 hours up to 20 measurements of thermo-emf, including the preparation of specimens and attending the furnace.

SUMMARY

The utilization of the melting point of palladium by the method described in this article yields satisfactory results and has proved a reliable method of improving the calibration of rare-metal thermocouples in the region of high temperatures. The method can be recommended as an addition to normal calibration extending only to 1200°C, and also for the regular inspection of high-temperature thermocouples working in furnaces at low immersion depths.

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THERMOMETRIC PLATINUM RESISTIVITY IN THE REGION OF LIQUID HELIUM TEMPERATURES

D. I. Sharevskaya and P. G. Strelkov

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In the region of liquid helium temperatures, platinum resistivity changes only slightly with changes in temperature, so that the resistivity value measured at 1-2° K can be considered as residual resistivity, i.e., as the resistivity at absolute zero. Residual resistivity characterizes the metal impurities and crystal lattice distortions and represents one of the basic electrical constants of the metal. The determination of the residual resistivity of various sorts of pure platinum is of special interest in connection with the character of changes in the $W_T = R_T/R_{0°C}$ value in dependence on temperature in the region below 40-50° K, where this constant can be a thermometric characteristic of different platinum varieties which would be of the same importance as the relative platinum resistivity $W_{100°C} = R_{100°C}/R_{0°C}$ at the normal boiling temperature of water.

We had the opportunity of measuring the residual resistivity of 11 varieties of platinum of different origins.

The sorts designated by IKh-3, IKh-4, IKh-5, and IKh-6 were refined, melted, and drawn in the laboratory of the Institute of General and Inorganic Chemistry, Academy of Sciences, USSR; platinum specimens designated by Pt-50, Pt-51, and P-12 represent domestic industrial platinum varieties; Am-I, Am-II, and Am-III are specimens of American plant-produced platinum;* finally, B designates a platinum thermometer sent by the National Physics Laboratory (C. R. Barber, Great Britain) for the purpose of comparing temperature scales in the region below 90° K.

The wires obtained from ten specimens were drawn in the laboratory until their diameters were equal to 0.05 mm. From these wires, P. G. Strelkov resistance thermometers [1] were prepared, which, after their surface was cleansed [2]; were sealed in glass vials filled with helium under reduced pressure and then annealed simultaneously at 450°C. The resistance of the thermometers at 0°C was close to 100 ohms.

In order to obtain information on the ratio of cold-worked to annealed platinum residual resistivity, we measured the resistance of several thermometers in liquid helium before annealing, after which these thermometers were, as was said above, annealed.

The resistance of the thermometers was measured in a liquid helium bath at two temperatures: at the normal boiling temperature (4.2° K) and under reduced vapor pressure, which corresponded to 1.5° K. The pressure was measured by means of a mercury gauge. The thermometers were mounted in a copper block, which was immersed in a Dewar flask with liquid helium. The measurements were performed by means of a low resistance potentiometer and a standard resistance coil according to the Disselhorst method. The intensity of the measuring current through the thermometer was maintained at 4 ma. The measuring circuit sensitivity made it possible to measure the resistance with a ± 0.01% error.

*The indicated specimens of thermometric platinum were sent for the purpose of study to one of the authors by the National Bureau of Standards, USA, in 1945.

TABLE 1

Thermometer	$W_{100°C}$	$W_{1.5°K}$	$W_{4.2°K}$	$W_{10.8°K}$	$W_{10.8°K} - W_{1.5°K}$	$W_{4.2°K} - W_{1.5°K}$
IKh-6	1.39251	$507 \cdot 10^{-6}$	$532 \cdot 10^{-6}$	$870 \cdot 10^{-6}$	$363 \cdot 10^{-6}$	$25 \cdot 10^{-6}$
B	250	460	485	827	367	25
P-12	247	820	845	1211	391	25
IKh-4	242	709	734	1083	374	25
Am-I	228	557	582	934	377	25
IKh-5	217	1191	1218	1585	394	27
Pt-51	215	1293	1320	1698	405	27
Am-III	209	909	935	1309	400	26
Am-II	206	1227	1253	1625	398	26
Pt-50	205	1337	1364	1742	405	27
Ikh-3	178	2109	2141	2532	423	32

TABLE 2

Thermometer	$\Delta W = W$ bef. ann. $- W$ aft. ann.	Thermometer	$\Delta W = W$ bef. ann. $- W$ aft. ann.
IKh-3	$12.100 \cdot 10^{-6}$	Am-I	$12.300 \cdot 10^{-6}$
IKh-4	13.900	Am-II	10.100
IKh-5	12.800	Am-III	19.800

The measurement results are shown in Table 1, which provides the values of $W_{100°C}$ and $W_{10.8°K}$ that were determined earlier [3] and the values of $W_{4.2°K}$ $W_{1.5°K}$, which were determined in our experiments.

Table 2 shows the results of a comparison between the residual resistivity of cold-worked (before annealing) platinum and that of annealed platinum. It is obvious that the change in the platinum residual resistivity due to annealing is much greater than the annealed platinum residual resistivity and that its magnitude is of the same order for platinum sorts of different purity and origin.

The experimental results shown in Table 1 indicate that while a smaller $W_{1.5°K}$ value more often corresponds to a larger $W_{100°C}$ value, there is no well-defined relationship between the values of these quantities. For instance, for the majority of platinum sorts produced abroad, a lower $W_{1.5°K}$ value is observed for a lower $W_{100°C}$ value in comparison with domestically produced platinum varieties. It should also be noted that the $W_{10.8°K} - W_{1.5°K}$ values and even the $W_{4.2°K} - W_{1.5°K}$ values (see Table 1) are not equal for all platinum sorts, as would follow from the assumption of the validity of Matthiessen's rule

$$R(T) = R_{id}(T) + R_{res}$$

where

$R_{id}(T)$ is the temperature-dependent resistance of "ideal platinum," and

R_{res} is the residual resistance, which is independent of temperature and which characterizes the given platinum sort.

The values of these differences vary from the purest variety to that with the greatest impurity content by 25% (25×10^{-6} and 32×10^{-6} for $W_{4.2°K} - W_{1.5°K}$ and by 15 (363×10^{-6} and 423×10^{-6}) for $W_{10.8°K} - W_{1.5°K}$. These results agree with those obtained earlier [4].

Thus, the experimentally obtained residual resistivity values for different platinum sorts compel us to reject the widely used representation of the electrical resistance of metals as the sum of two terms of Matthiessen's rule.

For an adequate description of the temperature dependence of platinum resistivity, an additional term which would characterize the given platinum variety and which would depend on temperature should be provided. As was shown by Kohler [5], such an expression for resistivity can be found by using the modern theory of metals.

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ELECTRICAL MEASUREMENTS

PRINCIPLES OF CONSTRUCTING AUTOMATIC AC BRIDGES WITH EXTREMAL REGULATION

F. B. Grinevich

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At the present, two types of automatic ac bridges for measuring complex impedances are known: bridges with separate balancing [1, 3, 7, 8], and bridges with phase-sensitive detectors (indicators) [2, 4, 5, 6]. Along with their advantages, these bridges also have some very important disadvantages of a fundamental nature.

The main disadvantage of bridges with separate balancing is that the error of their indications depends on the properties of the special separate balancing indicators, which are always made from low-stability elements (vacuum tubes, transistors). In spite of the fact that the separate balancing indicators are stabilized in one way or another, the instability of their elements causes a sharp increase in the measurement error. Significant errors in this type of bridges can also arise as a result of the shunting of some of the bridge arms by the input circuits of the separate balancing indicators.

The main disadvantage of automatic bridges with phase-sensitive detectors is the variable mutual coupling of the automatic regulation circuits. It is shown in [4, 6] that the mutual coupling of the balancing circuits in actually constructed automatic bridges leads to a decrease in the critical amplification factor, that is, in the final sense it leads to an increase in the static balancing error of the bridge. The presence of variable mutual coupling of the balancing circuits may also lead to a loss of stability in the control system at individual balance points (because of phase distortion, for example).

The errors of both types of automatic bridges depend to a large degree on distortions of the voltages powering the bridge circuit, on frequency changes, and also on a number of other factors, whose effect in nonautomatic bridges with amplitude null indicators can be made negligibly small. In automatic bridges of the types mentioned, protection from external and internal stray fields is complicated; it is practically impossible to use ordinary selective amplifiers.

Because of these facts, it becomes necessary to develop automatic bridges which will permit one to retain the measuring advantages of nonautomatic bridges with amplitude null indicators, and yet be simple in their circuitry and construction.

One method of doing this is to use extremal regulation methods for bridge balancing.

Let us examine the theoretical bases of using extremal regulation methods for balancing ac bridges.

The general problem of an extremal regulation system is the automatic search for an extremal value of some function. The basic characteristics of the result of the regulation process are the extremal value of the function and the search error of this value. In constructing automatic ac bridges, the basic problems are the automatic balancing of the circuit, and the measurement of the complex impedance. The basic characteristics of the result of the regulation process in this case are the parameters of the complex impedance, and their measurement errors. The method presented for automatic ac bridges is based on forming control signals which are a function of the amplitude of the bridge output voltage.

Let the bridge be balanced with the aid of two parameters, $\underline{p}$ and $\underline{q}$. Parameters $\underline{p}$ and $\underline{q}$ are controlled by certain signals U_p and U_q which are functions of the bridge output voltage. In general, $\underline{p}$ and $\underline{q}$ may be found in

different arms and different branches of the bridge circuit. The output voltage of any bridge circuit can be represented in the following general manner:

$$\dot{U}_{out} = \dot{U}_n W, \tag{1}$$

where $W = f(Z_1, Z_2 \ldots Z_i \ldots Z_n)$; Z_i are the impedances of the bridge arms.

Let p and q be modulated by functions with very small modulation amplitudes, Δp_0 and Δq_0. In this case, the frequencies of the sinusoidal modulating signals Ω_1 and Ω_2 are significantly less than the frequency ω of the bridge supply voltage U_n. Assuming that

$$\begin{aligned} \Delta p &= \Delta p_0 \sin \Omega_1 t; \\ \Delta q &= \Delta q_0 \sin (\Omega_2 t + \psi) \end{aligned} \tag{2}$$

and ignoring transients in the bridge circuit, one can obtain the following expression for the bridge output voltage $\dot{U}_{out}$:

$$\dot{U}_{out} = \dot{U}_n [W + W'_p \Delta p_0 \sin \Omega_1 t + W'_q \Delta q_0 \sin (\Omega_2 t + \psi)], \tag{3}$$

where W'_p and W'_q are derivatives of W with respect to p and q.

As can be seen from (3), the bridge output voltage is modulated both in amplitude and in phase, because of the modulation of p and q. We will use only the amplitude modulation in forming the regulating signals U_p and U_q.

Designating

$$\begin{aligned} \arg W &= \varphi, \\ \arg W'_p &= \varphi_1, \\ \arg W'_q &= \varphi_2 \end{aligned} \tag{4}$$

and performing a number of simple but lengthy transformations of (3), we get the following expression for the modulus of the bridge output voltage U_{out}:

$$\sqrt{|W|^2 + |W'_p|^2 (\Delta p_0)^2 \sin^2 \Omega_1 t + |W'_q|^2 (\Delta q_0)^2 \sin (\Omega_2 t + \psi) + 2 |W| |W'_p| \cos (\varphi_1 - \varphi) \Delta p_0 \sin \Omega_1 t + 2|W| |W'_q| \cos (\varphi_2 - \varphi) \Delta q_0 \sin (\Omega_2 t + \psi) + 2 |W'_p| |W'_q| \cos (\varphi_1 - \varphi_2) \Delta p_0 \Delta q_0 \sin \Omega_1 t \sin (\Omega_2 t + \psi).} \tag{5}$$

The envelope of the bridge output voltage U_{out}, detected by an ordinary high-frequency detector and filtered, can be used to form the regulating signals U_p and U_q. The parameters U_p and U_q, as functions of p and q, for balancing the bridge can be formed by using frequency or phase selection.

If frequency selection is used, U_p and U_q are formed with the aid of selective amplifiers which detect voltages of frequencies Ω_1 and Ω_2 from the envelope of U_{out}, and with the aid of phase-sensitive detectors. It can be shown on the basis of expression (5) that if the ratio of frequencies Ω_1 and Ω_2 is a fraction whose numerator and denominator are not even numbers, the signals on the output of the phase-sensitive detectors will uniquely depend on the functions

$$\begin{aligned} &2 |W| \cdot |W'_p| \cos (\varphi_1 - \varphi); \\ &2 |W| \cdot |W'_q| \cos (\varphi_2 - \varphi), \end{aligned} \tag{6}$$

respectively.

After suitable amplification, these signals are used as the regulating signals U_p and U_q. Regulating signals can be formed analogously by using one of the odd harmonics of Ω_1 or Ω_2.

If phase selection is used, the regulating signals U_p and U_q are formed with the aid of phase-sensitive detectors whose control voltagesare in phase with the modulation signals

$$\Delta p = \Delta p_0 \sin \Omega t,$$
$$\Delta q = \Delta q_0 \sin\left(\Omega t + \frac{\pi}{2}\right), \tag{7}$$

respectively, at frequency Ω. The phase-sensitive detectors form signals which depend uniquely on (6) from the envelope of the bridge output voltage U_{out} as defined by expression (5) for $\Omega_1 = \Omega_2 = \Omega$, and $\psi = \pi/2$. As in the preceding case, these signals are used as the regulating signals U_p and U_q, after suitable amplification.

Automatic bridge balancing, both in the case of frequency and phase selection, basically reduces to the following. If the bridge is unbalanced both with respect to p and with respect to q, both regulating signals U_p and U_q generally arise. Under the action of U_p and U_q, the actuating mechanisms attempt to give p and q values which will result in relative minimums in the amplitude of the output voltage U_{out}, both with respect to p and with respect to q. Since $\cos(\varphi_1 - \varphi)$ never equals zero if $\cos(\varphi_2 - \varphi) = 0$, and conversely, the functions (6), on which U_p and U_q uniquely depend, can equal zero simultaneously only when $W = 0$, that is, when the bridge is balanced. The regulating signals U_p and U_q will also equal zero in this case. If the dynamic characteristics of the system are suitably chosen, the bridge will reach a stable state of balance.

Studies show that automatic ac bridges constructed according to the principles examined above will have all the measuring advantages of nonautomatic bridges with amplitude null indicators, and will have satisfactory dynamic characteristics. In these bridges, the amplifier-converter network plays only the role of a null indicator, as in nonautomatic bridges with amplitude null indicators. Therefore, no special requirements on the stability of the characteristics are imposed on amplifiers and detectors in bridges based on extremal regulation methods. Selective amplifiers can be used here with success. Instability of phase and amplitude characteristics of such amplifiers does not play an important role. By using selective amplifiers at the bridge output, the effect of wave shape and noise can be reduced to a permissible minimum. The shielding of such automatic bridges from various disturbances is no more complex than the shielding of analogous models of nonautomatic bridges with amplitude null indicators. Coupling of the automatic control circuits in the bridges under consideration does not depend on the balance point of the bridge, but is constant for a given convergence angle γ. When $\gamma = \pi/2$, the control circuits will be independent (we have in mind couplings which arise during small departures of the system from balance). The circuit and construction of such bridges can be sufficiently simple, and they are no more complex than existing types of automatic bridges.

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TESTING CURRENT TRANSFORMERS WITH NONSTANDARD NOMINAL TRANSFORMATION COEFFICIENTS

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Differential apparatuses for testing current transformers are based on the comparison of the transformers being tested with a standard. A necessary condition for testing with such apparatuses is that the nominal transformation coefficients of the standard transformers and those being tested be equal.

A circuit is given below, and a method is described which permits testing by using type AIT differential apparatuses and similar devices even when the nominal transformation coefficients of the standard transformers and those to be tested differ somewhat from one another.

This circuit includes not one, but two standard transformers with identical ranges, as well as the differential apparatus and a specially made differential branch consisting of two well matched resistances, R_1 and R_2.

When a current transformer with a nominal transformation coefficient of $K_X = I_{1\,nx}/I_{2\,nx}$ where $I_{1\,nx}$ and $I_{2\,nx}$ are the nominal primary and secondary currents of the transformer, is tested according to the method described below, it is necessary to choose standard transformers with a nominal coefficient of $K_0 = I_{1\,n0}/I_{2\,n0}$ so that K_0 is as close to K_X as possible. It is desirable that the difference between K_X and K_0 not be greater than 20% of the larger of the two.

I. To begin with, let us assume that $K_X < K_0$, that is, the nominal primary current of the transformer being tested $I_{1\,nx}$, is less than that of the standard transformer, $I_{1\,n0}$ (Fig. 1).

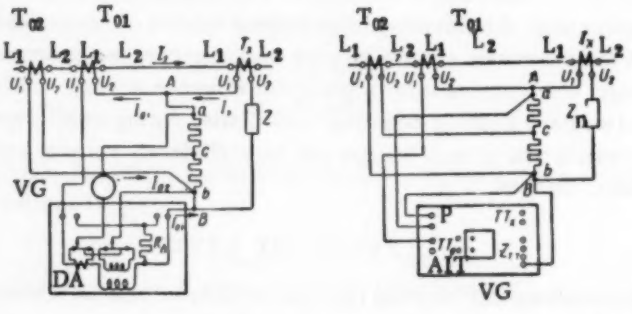

Fig. 1. Testing circuit for the case when $K_X < K_0$: a) schematic circuit diagram; b) the same circuit for the AIT apparatus. T_X) transformer being tested, with secondary current I_X; T_{01}) main standard transformer, with secondary current I_{01}; T_{02}) auxiliary standard transformer with secondary current I_{02}; DA) differential apparatus; VG) vibration galvanometer serving as a null indicator; Z_n) resistance box used to create the necessary load on the transformer being tested. The compensation circuit (terminals P) must be electrically isolated from the working circuit current. This is ensured by putting the measurement range switch of the volt-ammeter in the "5 amp" position, and by putting the apparatus measurement range switch in the "Z impedance measurement" position.

The voltage drop across the differential branch (between points a and b), which consists of resistances R_1 and R_2 (not in the AIT apparatus), can be balanced by voltages U_ϕ and U_δ, which are taken from the slide wire rheostats of the differential apparatus. Current I_{01} flows through the working circuit of the latter, as can be seen from Fig. 1. It is convenient to make R_1 equal to the differential resistance of the apparatus at its basic measurement range. It equals one ohm for the AIT. Resistance R_2 must be made equal to

$$R_2 = R_1 \frac{K_o - K_x}{2K_x - K_o} = R_1 \frac{I_{1n_o} - I_{1n_x}}{2I_{1n_x} - I_{1n_o}}. \quad (1)$$

The test is performed in the following way. Having assembled the circuit and established the desired primary current I_{01}, it is balanced by turning the rheostat knobs of the apparatus.

The voltage drop between points a and b, generated by currents I_X, I_{01} and I_{02}, equals

$$\dot{U}_{ab} = (\dot{I}_x - \dot{I}_o)(R_1 + R_2) - \dot{I}_{o_2} R_2. \quad (2)$$

At balance, it equals the voltage $\dot{U}_k$ taken from the rheostats:

$$\dot{U}_k = \dot{I}_{o1} \frac{f_a\%}{100} R_{\Delta H} + j\dot{I}_{o1} \cdot 2.91 \cdot 10^{-4} \delta'_a R_{\Delta H}, \quad (3)$$

where f_a %, δ'_a are the apparatus readings; $R_{\Delta H}$ is the nominal resistance of the differential branch of the apparatus.

At balance, $\dot{U}_{ab} = \dot{U}_k$, and

$$(\dot{I}_x - \dot{I}_{o1})(R_1 + R_2) - \dot{I}_{o2} R_2 = \dot{I}_{o1}\left(\frac{f_a\%}{100} + j \cdot 2.91 \cdot 10^{-4}\right) R_{\Delta H}. \quad (4)$$

Let us call λ_X, λ_{01}, and λ_{02} the complex errors of the test, standard, and auxiliary standard transformers respectively, and f_X%, f_{01}%, f_{02}% and δ'_X, δ'_{01}, δ'_{02} are respectively the errors of their transformation coefficients (in percent), and phase (in minutes). It is known that

$$\lambda_x = \frac{f_x\%}{100} + j \cdot 2.91 \cdot 10^{-4}\, \delta'_x = \frac{-K_x \dot{I}_x - \dot{I}_1}{I_1};$$

$$\lambda_{o1} = \frac{f_{o1}\%}{100} + j \cdot 2.91 \cdot 10^{-4}\, \delta'_{o1} = \frac{-K_o \dot{I}_{o1} - \dot{I}_1}{I_1}; \quad (5)$$

$$\lambda_{o2} = \frac{f_{o2}\%}{100} + j \cdot 2.91 \cdot 10^{-4}\, \delta'_{o2} = \frac{-K_o \dot{I}_{o2} - \dot{I}_1}{I_1};$$

$$\dot{I}_x = -\frac{\dot{I}_1}{K_x}(1 + \lambda_x); \quad \dot{I}_{o1} = -\frac{\dot{I}_1}{K_o}(1 + \lambda_{o1});$$

$$\dot{I}_{o2} = -\frac{\dot{I}_1}{K_o}(1 + \lambda_{o2}). \quad (6)$$

We will further designate Δ_1 and Δ_2 as the resistance errors of R_1 and R_2, that is,

$$\Delta_1 = \frac{R_1 - R_{1n}}{R_{1n}} \text{ and } \Delta_2 = \frac{R_2 - R_{2n}}{R_{2n}},$$

from which we get

$$R_1 = R_{1n}(1 + \Delta_1) \text{ and } R_2 = R_{2n}(1 + \Delta_2). \quad (7)$$

Here R_{1n} and R_{2n} are the nominal values of R_1 and R_2.

Substituting the values of secondary currents and resistances from (6) and (7) into (4), we get

$$\left(\frac{1 + \lambda_x}{K_x} - \frac{1 + \lambda_{o1}}{K_o}\right)[R_{1n}(1 + \Delta_1) + R_{2n}(1 + \Delta_2)] - \frac{1 + \lambda_{o2}}{K_o} R_{2n}(1 + \Delta_2) = \frac{1 + \lambda_{o1}}{K_o} R_{\Delta H}\left(\frac{f_a\%}{100} + j \cdot 2.91 \cdot 10^{-4} \delta'_a\right). \quad (8)$$

Rearranging the terms, and ignoring second order terms containing squares or products of two errors, we get

$$(R_{1n}+R_{2n})+\lambda_x(R_{1n}+R_{2n})+\Delta_1 R_{1n}+\Delta_2 R_{2n}=$$
$$\frac{K_x}{K_o}\left(\frac{f_a\%}{100}+j\cdot\delta'_a\cdot 2.91\cdot 10^{-4}\right)R_{\Delta H}+\frac{K_x}{K_o}(R_{1n}+R_{2n})+$$
$$\lambda_{o1}\frac{K_x}{K_o}(R_{1n}+R_{2n})+(\Delta_1 R_{1n}+\Delta_2 R_{2n})\frac{K_x}{K_o}+ \tag{9}$$
$$\frac{K_x}{K_o}R_{2n}+\lambda_{o2}\frac{K_x}{K_o}R_{2n}+\frac{K_x}{K_o}\Delta_2 R_{2n}.$$

Condition (1) must be observed for the nominal values of R_1 and R_2. Then

$$R_{1n}+R_{2n}=\frac{K_x}{K_o}R_{2n}+\frac{K_x}{K_o}(R_{1n}+R_{2n}). \tag{10}$$

If R_{1n} is made equal to $R_{\Delta H}$, then, taking (10) into account we get

$$\frac{f_x\%}{100}+j\cdot 2.91\cdot 10^{-4}\delta'_x=$$
$$=\frac{2K_x-K_o}{K_o}\left(\frac{f_a\%}{100}+j\cdot 2.91\cdot 10^{-4}\delta'_a\right)+\lambda_{o1}\frac{K_x}{K_o}+ \tag{11}$$
$$+\lambda_{o2}\left(1-\frac{K_x}{K_o}\right)+\Delta_1\left(\frac{K_x}{K_o}-1\right)\left(2-\frac{K_o}{K_x}\right)+$$
$$+\Delta_2\left(\frac{K_o}{K_x}-1\right)\left(2\frac{K_x}{K_o}-1\right)$$

from (9) by using (1).

The phase errors of resistances R_1 and R_2 are easy to make as small as desired, so that Δ_1 and Δ_2 can be considered as real numbers. Therefore, we get

$$f_x\%=\frac{2K_x\ K_o}{K_o}f_a\%+\frac{K_x}{K_o}f_{o1}\%+$$
$$+\left(1-\frac{K_x}{K_o}\right)f_{o2}\%-\left(1-\frac{K_x}{K_o}\right)\left(2-\frac{K_o}{K_x}\right)\Delta_1\cdot 100+ \tag{12}$$
$$+\left(\frac{K_o}{K_x}-1\right)\left(2\frac{K_x}{K_o}-1\right)\Delta_2\cdot 100;$$
$$\delta'_x=\frac{2K_x-K_o}{K_o}\delta'_a+\frac{K_x}{K_o}\delta'_{o1}+\left(1-\frac{K_x}{K_o}\right)\delta'_{o2} \tag{13}$$

by separating the real and imaginary parts of (11). It is desirable that R_1 and R_2 be matched accurately enough so that the last two terms in (12) and (13) can be neglected.

Then the computational formulas assume the following form:

$$f_x\%=(2a-1)f_a\%+af_{o1}\%+(1-a)f_{o2}\%;$$
$$\delta'_x=(2a-1)\delta'_a+a\delta'_{o1}+(1-a)\delta'_{o2} \tag{14}$$

where

$$a=\frac{K_x}{K_o}=\frac{I_{1nx}}{I_{1no}}.$$

In determining transformer phase errors, one must keep the following in mind.

The basic standard transformer is loaded during test only by the working circuit of the differential apparatus, as in ordinary tests. Resistances $R_1 + R_2$ do not appear as a load, since the voltage between points a and b is nearly zero.

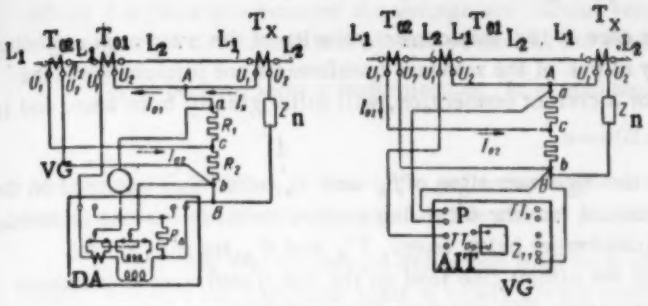

Fig. 2. Testing circuit for the case when $K_x > K_0$. Designations are the same as in Fig. 1.

During test, the auxiliary standard transformer is loaded by a resistance equal to

$$Z_{n2} = \frac{\dot{U}_{bc}}{\dot{I}'_{o2}} = \left(2 - \frac{K_o}{K_x}\right) R_2. \qquad (15)$$

II. Let us examine the second case when $K_x > K_0$, that is, $I_{1nx} > I_{1n0}$ (Fig. 2). Resistances R_1 and R_2 must be selected so that

$$R_2 = R_1 \left(\frac{K_x}{K_o} - 1\right). \qquad (16)$$

The following equation is the condition for circuit balance:

$$(\dot{I}_x - \dot{I}_o)(R_1 + R_2) + \dot{I}_{o2} R_2 = \dot{I}_{o1} R_{\Delta H} \left(\frac{f_a\%}{100} + j \cdot 2{,}91 \cdot 10^{-4} \delta'_a\right). \qquad (17)$$

Substituting the value of I and R from (6) and (7), and remembering that $R_{1n} + R_{2n} = R_{1n} K_x / K_0$ according to (16), and neglecting second order terms, we get

$$\lambda_x = \frac{K_x}{K_o} \cdot \frac{R_{\Delta H}}{R_{1n} + R_{2n}} \left(\frac{f_a\%}{100} + j \cdot 2{,}91 \cdot 10^{-4} \delta'_a\right) + \lambda_{o1} \frac{K_x}{K_o} - \lambda_{o2} \frac{K_x}{K_o} \cdot \frac{R_{2n}}{R_{1n} + R_{2n}} + \Delta_1 \left(\frac{K_x}{K_o} - 1\right) \frac{R_{1n}}{R_{1n} + R_{2n}} - \Delta_2 \frac{R_{2n}}{R_{1n} + R_{2n}}. \qquad (18)$$

It also follows from (16) that

$$\frac{R_{1n}}{R_{1n} + R_{2n}} = \frac{K_o}{K_x}; \quad \frac{R_{2n}}{R_{1n} + R_{2n}} = \frac{K_x - K_o}{K_x}.$$

Substituting these values and setting $R_{\Delta H} = R_{1n}$, we get

$$\lambda_x = \frac{f_x\%}{100} + j \cdot 2{,}91 \cdot 10^{-4} \delta'_x = \frac{f_a\%}{100} + j \cdot 2{,}91 \cdot 10^{-4} \delta'_a + \lambda_{o1} \frac{K_x}{K_o} - \lambda_{o2} \frac{K_x - K_o}{K_o} + \Delta_1 \frac{K_x - K_o}{K_x} - \Delta_2 \frac{K_x - K_o}{K_x}. \qquad (19)$$

Separating the real and imaginary parts, we get

$$f_x\% = f_a\% + \frac{K_x}{K_o} f_{o1}\% - \left(\frac{K_x}{K_o} - 1\right) f_{o2}\% + \left(1 - \frac{K_o}{K_x}\right)(\Delta_1 - \Delta_2) \cdot 100; \qquad (20)$$

$$\delta'_x = \delta'_a + \frac{K_x}{K_o} \delta'_{o1} - \left(\frac{K_x}{K_o} - 1\right) \delta'_{o2}.$$

During test, the auxiliary standard transformer is loaded by the resistance

$$Z_{n2} = \frac{\dot{U}_{bc}}{\dot{I}_{o2}} = R_2 \frac{\dot{I}_x + \dot{I}_{o2} - \dot{I}_{o1}}{\dot{I}'_{o2}} \simeq \frac{I_x}{I_{o2}} R_2 = R_2 \frac{K_x}{K_o}.$$

In using the methods described above, the following things must be kept in mind:

1. When the circuit is assembled, one must take care to see that correct polarity of the transformer windings is maintained. If the wires connected to the secondary of one of the standard transformers are interchanged, the voltage between points a and b, which is nearly zero for a correct connection, will differ greatly from zero, and it will be impossible to balance the circuit.

2. In measuring, it is easy to be mistaken about the algebraic signs of f_a and δ_a, when they are read on the scale of the apparatus. To avoid such errors, we recommend that the following method be used: having assembled and balanced the circuit for a certain load Z_n' on the transformer being tested, f'_a and δ'_a are read on the apparatus scale. Then, without changing the currents in the circuit, the load on the test transformer is increased so that the new balance readings f''_a and δ''_a will be noticeably different from the preceding ones, but will have the same sign. Since the algebraic magnitude of f_a must decrease as the load is increased, if the absolute value of f_a decreases ($|f''_a| < |f'_a|$) as the load is increased, a "+" sign must precede the readings of f_a. If, however, $|f''_a| > |f'_a|$, the reading must be preceded by a "−" sign. After these trials, it is recommended that the circuit connections be reversed, if necessary, so that the scale readings will give the correct sign of f_a. Then in all future tests, the values of f_a and δ_a can be read in the same manner as in ordinary tests, that is, as algebraic magnitudes.

3. Resistances R_1 and R_2 must be made, since it is not possible to use available resistance coils because the wire which connects R_1 and R_2 introduces a very large error. It is recommended that both resistances be made from one piece of wire (tape) by arranging it as shown in Fig. 3. Having chosen the over-all length of the wire so that its resistance is somewhat greater than the desired value $R_1 + R_2$, a tap for the potential terminal c should first be made. Then R_1 and R_2 are matched by choosing appropriate places for terminals a and b. Precise matching can be done after soldering on terminals a and b by filing the wire, soldering on tin, or by other methods. During matching, resistances R_1 and R_2 must be measured by the compensation method, or with a double bridge.

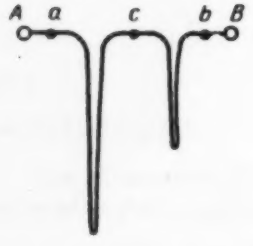

Fig. 3. Resistance R_1 (R_2); A and B are the current terminals; a, c, and b are the potential terminals.

4. Instead of an auxiliary standard transformer, a precise current transformer T_{aux} with a transformation coefficient of 5/5 can be used by connecting its primary winding into the secondary circuit of the basic standard transformer. In this case, the terminals of resistance R_2 (c and b) must be connected to the secondary leads of T_{aux}. If such a transformer is used, one must keep in mind that the load presented to the basic standard transformer by T_{aux} must be accounted for when the errors of the basic standard are determined.

POWER MEASUREMENT ERRORS IN AC CIRCUITS

V. S. Skryabinskii

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The operation of wattmeters in single- and three-phase ac circuits is analyzed in this article, and practical recommendations on estimating the measurement error in such circuits are given.

All-Union State Standard 8476-60 on wattmeters deals with the deflection of the instrument needle from the zero mark under nominal circuit load, and $\varphi = 90°$. This deflection is explained by the incomplete compensation for instrument phase errors. The angular error of the instrument, in percent, is

$$\gamma_\delta = 0{,}0291\delta \cdot \operatorname{tg} \varphi, \qquad (1)$$

where δ is the angle between the voltage and current vectors in the parallel circuit of the meter; φ is the phase angle between the voltage and current vectors in the load.

Let us perform some transformations. In accordance with the vector diagram (Fig. 1), we can write

$$\alpha = kUI \sin \delta, \tag{2}$$

where $\varphi = 90°$, where α is the needle deflection angle from the zero mark, due to the presence of δ; U is the voltage across the parallel circuit; I is the current in the series circuit of the wattmeter.

Considering that the needle deflection from zero when $\varphi = 90°$ must not exceed the values of the basic error, and that the wattmeter scale is nearly always uniform, we can write

$$C = \frac{\alpha}{\alpha_H}, \tag{3}$$

where C is the instrument class; α_H is the full needle deflection angle.

Thus,

$$C = \frac{kUI \sin \delta}{kU_H I_H \cos \varphi_H} \cdot 100; \tag{4}$$

Assuming that δ does not exceed 30-40', we obtain

$$\delta = \frac{CP_H}{UI \cdot 100}. \tag{5}$$

from (4), by setting $U_H I_H \cos \varphi_H = P_H$. Converting the value of δ in (5) from radians into minutes of arc, and substituting it in (1), we get

$$\gamma_\delta = \frac{CP_H}{UI} \operatorname{tg} \varphi \%. \tag{6}$$

This equation gives the expression for the angular error in terms of the accuracy class of the instrument.

The complete power measurement error is equal to the sum of the basic error of the meter and the angular error:

$$\gamma_{me} = (\gamma_p + \gamma_\delta)\% =$$

$$\frac{CP_H}{UI}\left(\frac{1}{\cos \varphi} + \operatorname{tg} \varphi\right)\%. \tag{7}$$

This formula permits one to determine the resultant relative power measurement error under any load in percent of the measurement results.

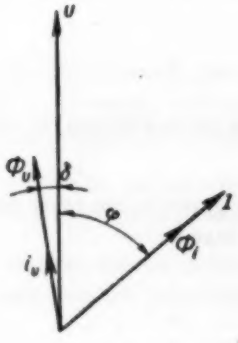

Fig. 1.

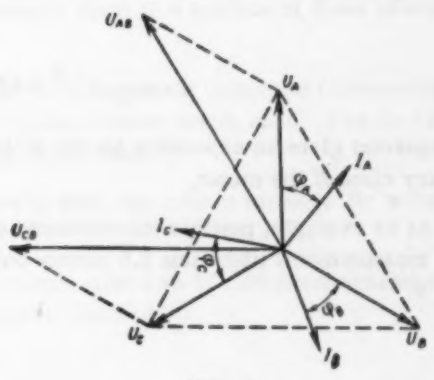

Fig. 2.

Formula (7) is justified only in calculating the measurement errors of ordinary wattmeters, where $\cos \varphi_H = 1$. If a small-cosine wattmeter is used for measuring, the resultant error can be determined with sufficient accuracy from the formula

$$\gamma_{me} = \frac{CP_H}{P} \%, \tag{8}$$

where P is the wattmeter reading.

As can be seen from a comparison of (7) and (8), the use of small-cosine wattmeters decreases the error by a large factor when the angle φ is large.

Let us examine the power measurement errors in a three-phase circuit in which power is measured by the two-wattmeter method. As a rule, the wattmeters used in such a circuit are intended for operation where $\cos \varphi_H = 1$. Since the operating conditions in this circuit differ from the nominal, significant additional errors appear.

The vector diagram of voltages and currents in a two-wattmeter circuit is shown in Fig. 2. In plotting the diagram, it was assumed that all three phases were uniformly loaded. This assumption will be made in all further discussions.

Since both meters in the indicated circuit operate as ordinary single-phase instruments, it can be said that the measurement error of the first meter will be

$$\gamma_{me1} = \frac{C_1 P_{H1}}{U_1 I_1} \left[\frac{1}{\cos (\varphi + 30^\circ)} + \operatorname{tg} (\varphi + 30^\circ) \right]. \tag{9}$$

The measurement error of the second meter will be

$$\gamma_{me2} = \frac{C_2 P_{H2}}{U_2 I_2} \left[\frac{1}{\cos (\varphi - 30^\circ)} + \operatorname{tg} (\varphi - 30^\circ) \right]. \tag{10}$$

As a rule, two completely identical meters are used in two-wattmeter power measurements, and consequently, $C_1 = C_2$, and $P_{H_1} = P_{H_2}$. Moreover, under uniform load $U_1 = U_2$, and $I_1 = I_2$. If now the errors γ_{me1}, and γ_{me2}, are transformed from relative into absolute quantities ΔP_1 and ΔP_2, and some manipulating is done, we can get a formula which is useful for finding the maximum possible error in three-phase power measurements made by the two-wattmeter method:

$$\gamma_{me} = \frac{\Delta P_1 + \Delta P_2}{P_1 + P_2} =$$

$$\frac{CP_H}{P_1 + P_2} \left\{ \left[\frac{1}{\cos (\varphi + 30^\circ)} + \operatorname{tg} (\varphi + 30^\circ) \right] \cos (\varphi + 30^\circ) + \right. \tag{11}$$

$$\left. \left[\frac{1}{\cos (\varphi - 30)} + \operatorname{tg} (\varphi - 30^\circ) \right] \cos (\varphi - 30^\circ) \right\}.$$

Neglecting second order terms, we can write

$$\gamma_{me} = \frac{2CP_H}{P_1 + P_2} (1 + 0.867 \sin \varphi). \tag{12}$$

This equation gives an expression for the relative error in two-wattmeter power measurements in terms of the accuracy class of the meter.

As an example, possible measurement errors for different values of φ are given in the table for two-wattmeter measurements with class 0.5 meters under nominal voltage and current load.

$\varphi°$	0	20	40	50	60	70	75	80	85
γ_{me},%	0.58	0.8	1.17	1.5	2.0	3.1	4.1	6.2	12.5

It can be seen from the table that the measurement errors for large values of φ, approaching 90°, become quite large. However, small-cosine meters cannot be used here as they can in the single-phase case, since each of the wattmeters operates in a mode unsuitable for small-cosine wattmeters. Thus, for example, when $\varphi = 85°$, $\cos \varphi_{n1} = 0.423$ for the first wattmeter, and $\cos \varphi_{n2} = 0.572$ for the second wattmeter.

Class 0.1 wattmeters are recommended for reducing three-phase measurement errors when φ is large. However, even in this case the measurement error may reach 2.5% when $\varphi = 85°$.

UNIVERSAL VOLT-AMMETERS

N. I. Tyurin, A. M. Lyubarskaya, and V. P. Boguslavskii

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 27-30, December, 1960

The growth of various branches of technology continuously imposes new requirements on electrical measuring instruments, such as extending the range and type of measurement, increasing the frequency range, increasing the accuracy, decreasing the power required by the instrument, and decreasing the response time. These meters must also be easily switched from one range to another, have minimum size and weight, must be transportable, provide storage space for the connecting leads and auxiliary attachments used to increase the measurement range, etc.

It is practically impossible to combine all these requirements in one instrument, which is one reason why so many types of volt-ammeters exist. At present, more than 10 companies produce 20 varieties of universal meters; 17 of these have passed government specifications in the VNII Committee of Standards, Measurements, and Measuring Instruments. The latest achievements in the instrument construction field, the accumulated experience of manufacturing, and mainly, field use now permit one to pose the question of developing, and to develop a rational series of universal volt-ammeters which would reduce the unjustifiably large number of types.

This series must have the least number of different types, and must satisfy all the requirements.

Let us first examine the parameters which characterize the meters now produced domestically (Table 1).

The first four meters are the most universal. They make it possible to measure six or seven different things, with 30-32 measurement ranges each. The oldest meter, the AVO-5M1, attracts one's attention in this group. Although it is inferior to the other three meters in accuracy, it exceeds them in a number of cases in measurement range.

The next four meters make it possible to measure five of the most important quantities (alternating and direct currents, voltages, and resistances), and have from 26 to 38 measurement ranges each. The Ts-51 meter has the widest measurement range in comparison to the remaining instruments.

There are also meters which differ from the preceding ones in that they cannot measure dc voltages or resistance, but have 18 to 26 measurement ranges each.

The last two meters make dc measurements of only three things, with 8 to 12 measurement ranges each. It can be seen that the universality of the last two meters is extremely limited.

TABLE 1

Factory designation of the volt-ammeter, and accuracy class (first figure is for DC and second for AC)	Upper limits and number of measurement ranges					Total number of measurement ranges
	current		voltage		Resistance	
	dc	ac	dc	ac		
AVO-5M1[1] 4,0; 4,0	60 μa – 12 amp (7)	3 ma – 12 amp (5)	3 v – 6 kv (7)	3 v – 6 kv (7)	3000 ohm – 30 meg (3)	30
P-52[1] 1,5; 2,5	150 μa – 1,5 amp (6)	3 ma – 1,5 amp (5)	75 mv – 600 v (8)	3 – 600 v (7)	10 kohm – 10 meg (4)	32
P-55[1] 2,5; 4,0	300 μa – 15 amp (6)	0,3 ma – 1,5 amp (6)	75 mv – 600 v (7)	750 mv – 600 v (7)	20 kohm – 20 meg (4)	32
P-57[1] 1,5; 2,5	150 μa – 1,5 amp (6)	3 ma – 1,5 amp (5)	75 mv – 600 v (8)	3 – 600 v (7)	3 kohm – 3 meg (4)	32
P-51[2] 1,0; 1,5	75 μa – 1,5 amp (8)	3 ma – 1,5 amp (8)	3 – 600 v (9)	3 – 600 v (9)	3 kohm – 30 meg (4)	38
P-56 1,0; 1,5	300 μa – 6 amp (9)	1,5 ma – 6 amp (9)	75 mv – 600 v (8)	0,3 – 600 v (8)	10 kohm – 10 meg (4)	38
TT-P 2,5; 4,0	150 μa – 0,5 amp (5)	0,5 ma – 0,5 amp (4)	0,5 v – 1,5 kv (7)	5 v – 1,5 kv (5)	1 kohm – 10 meg (5)	26
Ts-315 1,5; 2,5	1000 μa – 5 amp (8)	2,5 ma – 5 amp (7)	2,5 v – 1 kv (7)	2,5 v – 1 kv (7)	1 kohm – 1 meg (4)	33
TT-3 2,5; 2,5	100 μa – 3 amp (6)	–	100 mv – 1 kv (8)	1 v – 1 kv (7)	2 kohm – 20 meg (5)	26
TL-4 2,5; 4,0	100 μa – 3 amp (6)	–	100 mv – 1 kv (8)	1 v – 1 kv (7)	2 kohm – 20 meg (5)	26
Ts-20 4,0; 4,0	300 μa – 0,75 amp (5)	–	1,5 – 600 v (5)	7,5 – 600 v (4)	1 kohm – 1 meg (4)	18
Ts-21 2,5; 4,0	300 μa – 1,5 amp (5)	–	1,5 – 600 v (5)	1,5 – 750 v (4)	500 ohm – 500 kohm (4)	18
PR-5M 2,5; 4,0	60 μa – 0,6 amp (5)	–	6 – 600 v (4)	6 – 600 v (4)	500 ohm – 5 meg (5)	18
Ts-759 1,5; 2,5	1,5 ma – 7,5 amp (5)	15 ma – 7,5 amp (5)	1,5 – 300 v (6)	1,5 – 300 v (6)	–	22
Ts-760 1,5; 2,5	15 ma – 15 amp (5)	15 ma – 15 amp (5)	0,3 – 300 v (8)	0,3 – 300 v (8)	–	26
M-493 2,5; 4,0	3 ma – 3 amp (5)	–	3 – 600 v (5)	–	30 – 300 kohm (2)	12
M-360 2,5; 2,5	1,5 ma – 15 amp (4)	–	3 – 150 v (3)	–	5 kohm (1)	8

[1] The meters have scales for measuring transmission and attenuation levels, and for measuring capacitances.

[2] The Ts-51 volt-ammeter includes a shunt and current transformer which are intended to increase the dc measurement range of the meter to 15 amps, and the ac range to 30 amps.

TABLE 2

Factory designation of the volt-ammeter / Type of current	Ts-51, Ts-56	Ts-52, Ts-57, Ts-315, Ts-759, Ts-760	TT-3, N-360	Ts-55, Ts-21, PR-5M, TL-4, TT-11 M-493	AVO-5M1, Ts-20
	Permissible indication error of the meter, %				
Direct current	1.0	1.5	2.5	2.5	4.0
Alternating current	1.5	2.5	2.5	4.0	4.0

TABLE 3

Frequency range, cycles	Factory designation
Nominal	
50	Ts-56, AVO-5M1, Ts-20, Ts-21, Ts-759, Ts-760, PR-5M
To 500	Ts-52
To 1000	TT-3, TL-4, TT-P, Ts-315
To 1500	Ts-51
To 2000	Ts-55, Ts-57
Expanded	
To 1000	AVO-5M1, Ts-52
To 5000	Ts-20, Ts-21, Ts-51, Ts-55, Ts-57
To 10,000	TT-3, PR-5M, Ts-56, TL-4

TABLE 4

Factory designation of the volt-ammeter	Input resistance, kohm/volt	
	for dc measurements	for ac measurements
Ts-55	83.3	33
Ts-21	33.3	7
Ts-51, AVO-5M1, Ts-52, Ts-57, TT-P	20	2
PR-5M	16.7	–
TT-3, TL-4, Ts-20	10	3
Ts-315	1	0.4
Ts-56	0.7	0.7

Table 2 lists meters in order of their indication accuracy. The ac measurement error is higher, as a rule, than the dc. This is natural, since an additional element – the rectifier – enters the circuit. Two examples illustrate this. The dc measurement error of the Ts-20 meter was high, at 4%. Development of the meter increased the accuracy (see the Ts-21 meter). The designers of the TT-3 meter provided identical permissible errors for dc and ac measurements under engineering conditions. The manufacturer encountered production difficulties, and suggested that a variation of the meter with a higher ac measurement error be produced (the TL-4 meter), which would permit a considerable lowering of the cost of the meter. The examination of another variation in which the permissible dc measurement error would be lowered to 1.5% is certainly desirable.

The frequency range of the universal meters manufactured is quite varied; the upper limit of most of the meters depends on the measurement range. The nominal and expanded (with a two-fold increase in permissible error) frequency ranges for meters which have passed government specifications are given in Table 3. The maximum frequency range norm for all these meters is given.

The dc and ac input resistances, which characterize the power required by the meters, are shown in Table 4.

One of the foremost questions to be answered in the development of a new series of universal volt-ammeters is how to create a classification of instruments which satisfies the basic requirements of different branches of technology, and at the same time significantly reduces the number of different types of meters which must be produced.

The first attempts at classifying universal volt-ammeters were undertaken by the "Tochélektropribor" Plant, which divides universal meters into three groups, depending on their intended use.

The first group includes meters of the highest accuracy, intended for measurements under laboratory and industrial conditions; the basic error of these meters must not exceed ±1.0% at dc and ±1.5% at ac. The power consumption requirements for this group of instruments need not be very rigid, since they are intended for use in more or less powerful circuits. In these instruments, provision must be made to measure dc voltages up to 75 mv, for use with external shunts, and an upper limit of 5 to 6 amp must be provided for ac measurements in connection with a current transformer. Resistance measurements must range from fractions to thousands of ohms. Full scale meter deflection current may be on the order of 1-1.5 ma. The upper expanded frequency range (Table 3) should reach 10,000 cps.

Measurement of capacitance, transmission level, and attenuation is not possible with these instruments.

Instruments belonging to the second group are more universal, and are intended for use in communications, radio-electronic laboratories, for radio amateur use, etc. These meters must have a wider measurement range of current (10-15 amp), voltage (6000 v), and resistance, and must also make it possible to measure a capacitance, ac resistance, transmission level, attenuation, amplification, etc.

The full scale needle deflection current in these meters must not exceed 50 μa for dc, and 500 μa for ac.

The permissible dc error is ±1.5% , and ac error is ±2.5%.

Meters in the third group are characterized by extremely low power consumption; the full scale needle deflection current is between 10-20 μa. These meters are intended for measurements in low power dc circuits in cases where even the small amount of power consumed by meters in the second class would not be permissible due to significant distortions of the operating mode in the circuit being measured.

The "Tochélektropribor" Plant developed a basic group of universal meters in correspondence with the classification mentioned: Ts-55, Ts-56, and Ts-57 meters (see Table 1), which will be manufactured at the "Élektroizmeritel' " Plant.

The Ts-56 meter is classified in the first of the groups mentioned, the Ts-57 in the second, and the Ts-55 in the third.

The classification presented is only the first step in arranging and systemizing the requirements on universal meters manufactured by the domestic industry, since it by no means embraces all their complexity and interrelations. In particular, the requirements on meter accuracy are completely unrelated to field use conditions (temperature and humidity), and to the particular construction of the range switches.

The method of changing measurement ranges, the construction of switches, and the possible use of auxiliary apparatus for expanding measurement range are especially important in regard to use of universal meters.

Plug-board switching, used for example in the AVO-5M1, Ts-20, PR-5M, and TT-P meters, has a number of disadvantages: the possibility of mistakes in plugging, unreliable contact, and a large transfer resistance. Simplicity and cheapness are advantages of this kind of switching.

Switching by means of two rotary switches, used in the Ts-315, Ts-51, Ts-52, etc. meters, requires complex multi-wafer switches which are unreliable in use.

Three switches are used in the Ts-55, Ts-56, and Ts-57 meters for changing the measurement range (one is for switching the current measurement range, the second is for voltage range, and the third is the ac-dc selection switch). The presence of three switches makes it possible to measure consecutively current and voltage in two circuits having one common point. Moreover, the "division" of one switch into two makes it easier to increase the number of measurement ranges. Such a change makes it possible to use significantly simpler switch construction. However, the use of three switches demands great attention from the operator.

Universal meters with one switch (as produced by certain foreign firms) are not made in the USSR because of the complexity and unreliability of all known constructions of this type of switch. Recently, a new original "bus" type rotary switch has been developed, and is used in the TT-3 and TL-4 meters. In this switch, switching is accomplished on several annular buses placed in one plane; a contact plate, connected to an external rotary disc which indicates the switch position, slides along these buses. The switch is simple to use and cheap to produce, but its reliability has not yet been studied.

The majority of high-sensitivity universal meters have a meter movement with an inside-frame magnet, and with the movable part attached to struts. The repair of such an instrument is associated with well-known difficulties. Moreover, cases of wrong connections resulting in shock overloads are frequent due to the large number of measurement ranges. Considering the fields of use, the stability requirements on short-time overloads must be stiffened for this type of meter, or else overload protection must be provided. Naturally, these requirements cannot be met in all meters without exception; such requirements are conditional to the field of use, accuracy class, and meter construction.

The construction of the meter case must also be related to the permissible errors, field of use, and technico-economic factors, since additional requirements on the meter case arise in certain cases: portability, protection from mechanical shocks, and even splash-resistance, are examples. A certain group of meters must have special storage containers.

The problem of voltage dividers for expanding the voltage measurement range stands out sharply. The existing safety rules in the USSR do not subdivide meters into any sort of groups depending on their fields of use. For example, a test voltage of 13 kv is set for 6 kv voltage measurements, regardless of whether the given meter is used on circuits drawing light current or heavy current. Because of this, the R-515 and R-516 voltage dividers developed by the "Tochélektropribor" Plant are not permitted to be manufactured.

The question of the permissibility of using devices which extend voltage measurement range in low-current circuits, when the insulation strength of these devices does not meet present requirements, must be examined and defined more precisely. If this question is suitably answered, it may be possible to stop production of the AVO-5M1 volt-ammeter, an excessively large, obsolescent meter.

An exchange of opinions among a wide group of manufacturers and users concerning field use experience with meters can greatly help to solve the problems mentioned, and to create a rational classification system to ensure the production of modern, universal volt-ammeters which meet the demands of the people's economy.

TELEMETERING APPARENT POWER WITH A HALL-EFFECT TRANSDUCER

D. Frenkel' and V. Stoika

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 30-31, December, 1960

The apparent power of a transformer substation is an important characteristic. Under symmetrical load, it characterizes the over-all losses in the transformer, and moreover, gives an indication of the maximum real power which can be transmitted in the presence of given line losses. The measurement of the apparent power of transformer substations, and especially telemetering it, has great value. Therefore, a meter based on the use of the Hall effect was developed by the authors.

It is known that the voltage u_h across the output of a Hall transducer is proportional to the control current i_c flowing through the transducer, and to the magnetic field B in which it is placed. If the flux density B is proportional to the current used by the consumer, $B = k_i i$, and the current i_c is proportional to his supplied voltage, $i_c = k_u u$ (or conversely, if $i_c = k_i i$, and $B = k_u u$), the Hall voltage

$$u_h = kui = k[U_m I_m \cos\varphi - U_m I_m \cos(2\omega t - \varphi)],$$

where

$$u = U_m \sin \omega t;$$
$$i = i_m \sin (\omega t - \varphi).$$

In this case, the dc component of the Hall voltage is proportional to the real power used by the consumer, and the amplitude of the alternating component is proportional to the apparent power. In this way, it is possible to measure both the real and apparent power with one transducer.

Let us examine possible sources of error in measuring by means of this method.

The dependence of the ac Hall voltage component on the apparent power is not strictly linear, since the Hall constant decreases as the flux density increases. Thus a circuit must be chosen in which the flux density B is generated by a parameter which varies within narrow limits. In our case, this parameter is the voltage.

Systematic error can appear as a result of the emf induced in the Hall contact circuit by a variable magnetic field, and also as a result of the Hall electrodes being nonequipotential. Both errors can be decreased by appropriate construction: on one hand, the magnetic field surrounding the Hall electrode circuit is decreased by appropriate positioning of the wires, and on the other hand, these contacts are made so carefully that their nonequipotentiality is so small that there is no need for special compensation.

Another source of errors is the dependence of the Hall constant on temperature. The Hall constant decreases as the temperature increases. The resultant error can be eliminated by putting a suitable resistor in parallel with the control electrodes of the transducer.

This compensation method is based on the fact that as the temperature increases, the transducer resistance decreases, and this leads to an increase in the control current, thereby compensating for the lowering of the Hall constant.

The voltage across the Hall transducer output has an amplitude on the order of hundreds of millivolts, and can be measured with ordinary meters in ordinary measurements. Telemetering a short distance requires a large voltage in comparison with ordinary measurements. Therefore, in telemetering the apparent power, the ac Hall voltage component was separated from the dc by a transformer, and then amplified by an electronic amplifier with a sufficiently stable amplification factor. The ac voltage at the amplifier output was rectified by a germanium bridge, and measured with a milliammeter located at the other end of the telemetering channel. For nominal values of apparent power, the current in the channel is 1 ma for a channel resistance of 10,000 ohms. The complete measurement circuit is shown in Fig. 1.

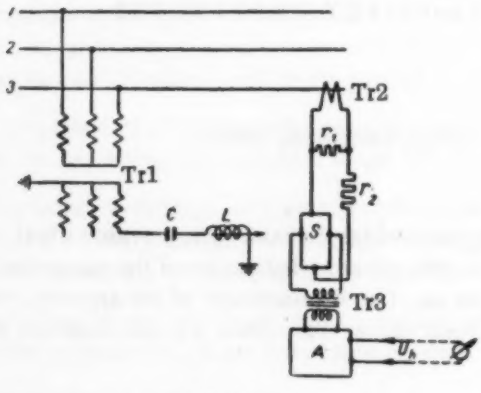

Fig. 1.

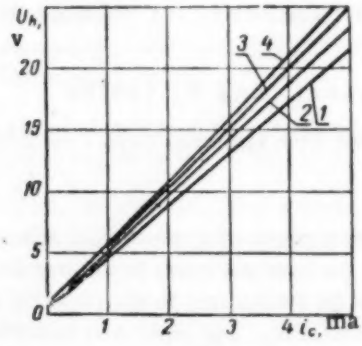

Fig. 2

1—50 v; 2—55 v; 3—60 v; 4—65 v.

The semiconductor transducer used was 6 × 3 × 0.5 mm in size, and was made from InSb; at 20°, the conductivity $\sigma = 60$ ohm^{-1} cm^{-1}, and Hall constant $R_h = 218$ cm$^3 \cdot$ k^{-1}. The flux density in the core at nominal voltage is B = 2000 gauss. The ac component of the Hall voltage, measured by a vacuum tube voltmeter, has an effective value which is strictly proportional to the control current i_c, but its dependence on B deviates from

linearity, causing relative errors less than 1%. In experiments, the magnetic flux density was generated by a voltage, and the current was proportional to the consumer's current. The control current was less than 100 ma.

Curves of the output voltage u_h as a function of load current I were plotted from experimental data for three values of U (Fig. 2). These dependencies deviate from linearity only in the parts near the origin ($I = 0.05\ I_{nom}$). This is explained both by the presence of an emf induced in the Hall contact circuit in the absence of a control current, and by amplifier noise. The relative measurement error in the circuit built did not exceed 3%.

SUMMARY

By using the Hall effect in semiconductor materials, it is possible to measure apparent power at a distance with satisfactory accuracy.

INSTABILITY OF QUARTZ CRYSTAL OSCILLATOR FREQUENCIES

F. F. Evstaf'ev

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 32-33, December, 1960

Below we give frequency-instability measurement results of surface and underground quartz-crystal oscillators of the KhGIMIP (Kharkov State Institute of Measures and Measuring Instruments) group frequency standard for various intervals of time (from two seconds to twenty-four hours), and we show to what extent the distribution of the frequency instability variations of highly stable quartz oscillators follows the law of normal distribution.

The surface oscillators operate with electron tubes kept together with quartz crystals in thermostats, whose temperature is maintained from day to day at about 39 ±0.01°C. The underground oscillators work with transistors and are kept in 25 m deep wells at a temperature of 10.1°C. The natural mean monthly temperature variations at this depth amount approximately to $\pm 10^{-4}$°C.

All oscillators of the group have quartz bars with a nominal frequency of 60 kc and a Q-factor of about $2.5 \cdot 10^5$.

At a temperature of 39°C the quartz bars have a zero frequency temperature coefficient. For a temperature of 38.5 ±0.5°C it does not exceed $5 \cdot 10^{-8}$ and for a temperature of 10°C it is equal to $3 \cdot 10^{-6}$.

The surface oscillators are fed from ac mains through rectifiers with constantly connected floating alkaline batteries. The underground oscillators are fed from dry galvanic cells with the supply voltage stabilized by means of floating grade 3 standard cells.

Short-term instability was determined by a series of measurements of the quartz oscillator periods by means of an instrument described in detail in [1].

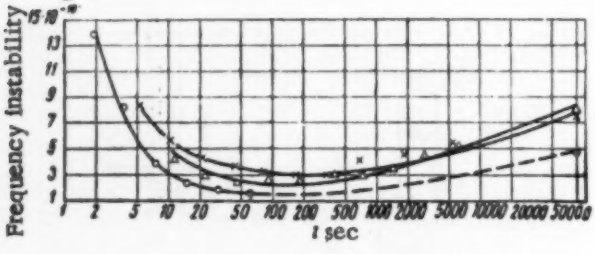

Fig. 1. x) Underground oscillators Nos. 2 and 4; Δ) surface oscillators Nos. 2 and 3; o) surface oscillators Nos. 2 and 4.

The error in measuring the frequency instability of the oscillators amounted for a two-second interval to $3 \cdot 10^{-10}$ and for a minute interval to $3 \cdot 10^{-11}$.

The daily frequency instability of the oscillators was measured by means of continuously operating oscillation counters with an error of $2 \cdot 10^{-10}$.

The regular daily drift of the oscillator frequency was excluded in determining the frequency instability. Thus, for the underground oscillators the regular daily frequency drift amounted to $+5 \cdot 10^{-10}$, and for surface oscillator No. 3 this value did not exceed $+1 \cdot 10^{-10}$. The regular frequency drift for hourly or smaller intervals was not taken into account at all, since it is negligibly small compared with the frequency instability for these intervals.

The mean value of an oscillation period for time t and a whole number n of counted periods is

$$F = f_1 - f_2 = \frac{n}{t} = \frac{1}{T}, \qquad (1)$$

where f_1 and f_2 are the crystal oscillator frequencies being compared; and T = t/n is the mean oscillation period.

Since time t of a whole number of periods n is measured, quantities t and T are variables, but n is a constant for the given series of measurements.

From (1) we obtain the variation in the frequency of oscillations:

$$\delta F_i=\delta f_{1i}-\delta f_{2i}=\frac{n\delta t_i}{t^2}=\frac{\delta t_i}{Tt}. \tag{2}$$

On the basis of the law for adding mean random quantities we obtain from (2), for a sufficiently large number N of series of measurements, the quadratic mean value of the oscillation variations:

$$\delta F_0=\sqrt{\delta f_1^2+\delta f_2^2}=\frac{\delta t}{T_0 t_0}, \tag{3}$$

where δf_1 and δf_2 are the quadratic mean values of the frequency variations of the oscillators being compared; t_0 and T_0 are the mean values of quantities t and T; and δt is the quadratic mean value for N measured variations of time $t = nT$.

For homogeneous generators of a group which have similar frequency instability ($\delta f_1 \simeq \delta f_2 \simeq \delta f$) we can obtain from (3) the oscillator frequency instability in terms of the relative quadratic mean variation:

$$\frac{\delta f}{f}=\frac{\delta t}{f t_0 T_0 \sqrt{2}}. \tag{4}$$

It follows from (4) that for a constant relative quadratic mean error of measuring time, equal to $\delta t/t_0$, the error of measuring the oscillator frequency instability is inversely proportional to the period of oscillation.

The frequency instability measurements for various time intervals are shown in Fig. 1 in the form of curves on a semilogarithmic scale.

Figure 2 shows the distribution of the frequency instability variations in the shape of "columns" for groups of surface and underground oscillators in five- and eleven-second and twenty-four intervals. Theoretical Gaussian curves obtained from probability density tables for a normalized standard distribution were also plotted on the graph for comparing them with empirical distribution. The theoretical number of variations was calculated for each group from a table of $\Phi(z)$ Laplace functions.

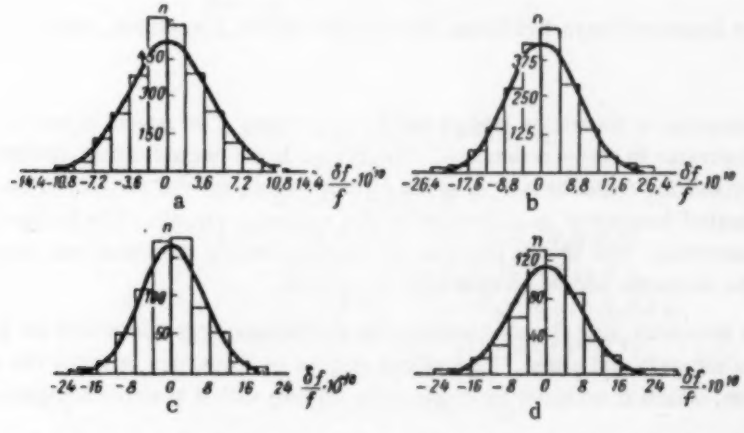

Fig. 2. a) 2,844 eleven-second variations of surface oscillators Nos. 2 and 3; b) 1,986 five-second variations of underground oscillators Nos. 2 and 4; c) 694 daily variations of surface oscillator No. 3; d) 528 daily variations of underground oscillator No. 4.

These tests have shown that empirical distribution agrees fairly well with normal distribution; for a large number of measurements the number of positive and negative variations is about equal. The probability (frequency) of variations is a decreasing function of their values. Very large values of frequency instability variations were not encountered.

The latter fact is confirmed by the maximum possible (limiting) frequency instability variations calculated on the basis of the Chauvenet criterion of rough errors.

Variations exceeding the limiting values amounted to 0.04% out of 2,844 variations, 0.05% out of 1,986 variations, 0.15% out of 694 variations, and 1.0% out of 528 variations.

SUMMARY

1) From the above relation of the oscillator frequency instability to the measuring time intervals it follows that the short-term frequency instability rises with a decreasing time interval smaller than one minute. For an interval of 1.9 sec it amounts to $14 \cdot 10^{-10}$ (Fig. 1, surface oscillators Nos. 2 and 4). The minimum value of the frequency instability of underground and surface oscillators lies in the limits of 1-4 minutes and is equal approximately to $(2\text{-}3) \cdot 10^{-10}$. For time intervals above that value the frequency instability increases again and for a 24-hour frequency instability amounts to $(4.8\text{-}7.8) \cdot 10^{-10}$ for surface and to $7.4 \cdot 10^{-10}$ for underground oscillators.

2. The frequency instability of underground oscillators differs but little from that of surface oscillators.

3. The distribution of the frequency instability variations of quartz oscillators has a random nature and follows in the main the normal distribution law. This applies not only to the short-term, but also to the 24-hour frequency instability of oscillators which have steady stabilized supplies and temperature over long periods of time.

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TRANSISTORIZED BRIDGE-TYPE QUARTZ-CRYSTAL OSCILLATORS

A. I. Aleksandrov

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 34-36, December, 1960

The oscillator comprises a resistance bridge and an amplifier. The quartz crystal is connected into one arm of the bridge and operates in series resonance. The bridge is connected either directly to the input of a transistor or through a matching transformer. A tuned circuit which, for the purpose of the analysis, is considered to be tuned to the generated frequency is connected to the collector circuit. The bridge is matched to this circuit by means of a transformer. The bridge resistors determine directly the phase and amplitude of oscillations and should, therefore, be as stable and as nonreactive as possible.

The effect of the transistor and circuit elements on the frequency is accounted for by means of the equivalent variations in the gain and phase. The effect of gain on frequency requires the stabilization of the amplitude of oscillations, which is attained by connecting a lamp with a positive temperature coefficient.

The system (Fig. 1a) will be unstable when the product of its gain K and loss β is equal to unity and the phase-shift in the amplifier is equal and opposite in sign to that in the circuit:

$$|K||\beta|=1; \quad \theta=-\psi. \tag{1}$$

The gain can be expressed in terms of the tuned circuit and transistor parameters [1].

The loss for the circuit in Fig. 1b can be written as

$$\beta = \frac{e}{E} = \frac{1}{a_{11}}.$$

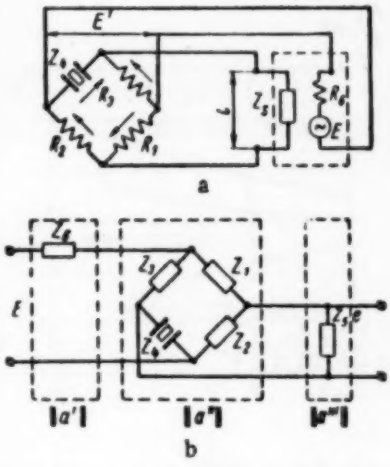

Fig. 1.

Coefficient a_{11} of the general quadripole matrix of the circuit will be [2]

$$a_{11} = a''_{11}(a'_{11}a^{*}_{11} + a'_{12}a^{*}_{21}) + a'''_{21}(a'_{11}a^{*}_{12} + a'_{12}a^{*}_{22}). \qquad (2)$$

By inserting the quadripole matrix elements from [2] into expression (2), we obtain

$$a_{11} = \left[\frac{(Z_1+Z_2)(Z_3+Z_4)}{Z_2Z_3 - Z_1Z_4} + Z_6\frac{Z_1+Z_2+Z_3+Z_4}{Z_2Z_3 - Z_1Z_4}\right] + \left[\frac{Z_1Z_2(Z_3+Z_4)+Z_3Z_4(Z_1+Z_2)}{Z_2Z_3 - Z_1Z_4} + Z_6\frac{(Z_1+Z_3)(Z_2+Z_4)}{Z_2Z_3 - Z_1Z_4}\right]\cdot\frac{1}{Z_5}. \qquad (3)$$

The input impedance of the circuit can be represented in the form

$$Z_5 = R_5 - jX_5.$$

Taking into consideration that the bridge is in a near-balanced condition, it is possible to find expressions for the input impedance components from [1].

By transforming (3) and taking into consideration that

$$Z_1 = R_1;\quad Z_2 = R_2;\quad Z_3 = R_3;\quad Z_4 = R_q + jX_q,$$

we have

$$\beta = \frac{AR_q - j(BX_q - B'X_5)}{MR_q - M'X_q + j(NX_q - N'X_5)}, \qquad (4)$$

where

$$\begin{gathered} A = R_5(R_2R_3 - R_1R_q) + R_1R_qX_5; \\ B = R_1R_qR_5; \\ B' = R_q(R_1R_q - R_2R_3); \\ N = R_q(R_1 + R_3 + R_5)(R_2 + R_6) + R_1R_4(R_3 + R_5); \\ N' = R_q(R_1 + R_2)(R_3 + R_q) + R_qR_6(R_1 + R_2 + R_3); \\ M = (R_1 + R_2)(R_3R_q + R_5R_6) + (R_3 + R_q)(R_1R_2 + R_5R_6) + \\ (R_5 + R_6)(R_1R_q + R_2R_3) + R_5(R_1R_3 + R_3R_q) + \\ R_6(R_1R_2 + R_3R_q); \\ M' = R_qX_5(R_1 + R_2 + R_6). \end{gathered} \qquad (5)$$

Taking $\dot{K} = K_x + jK_y$, it becomes possible to express the oscillating conditions (1) in the form

$$(K_x + K_y)\left[\frac{AR_q - j(BX_q - B'X_5)}{MR_q - M'X_q + j(NX_q - N'X_5)}\right] = 1, \qquad (6)$$

whence

$$K_x AR_q + K_y (BX_q - B'X_s) - (MR_q - M'X_q) = 0; \tag{7}$$

$$K_y AR_q - X_q (K_x B + N) + (K_x B' + N') X_s = 0. \tag{8}$$

Assuming in (7) $K_y = 0$, we can find the value of A, insert it in (8), and solving with respect to X_q we have

$$X_q = \frac{MR_q}{K_x B + N + \frac{K_y}{K_x} M'} \cdot \frac{K_y}{K_x} + \frac{(K_x B' + N') X_s}{K_x B + N + \frac{K_y}{K_x} M'}. \tag{9}$$

Taking into consideration that

$$\frac{f - f_q}{f_q} = \frac{X_q}{2Q_q R_q},$$

we shall have for small angles

$$\frac{f - f_q}{f_q} = \frac{1}{2Q_q} \times \left[\frac{M\Theta}{B|K| + N + M'\Theta} + \frac{(B'|K| + N') X_s}{(B|K| + N + M'\Theta) R_q} \right], \tag{10}$$

where Θ is the phase-shift in the amplifier.

As it has been pointed out, the above expression is accurately applicable if Θ is small, as it should be in a well-designed amplifier.

Assuming that in (10) $B' = 0$ and differentiating with respect to K, we have

$$\frac{df}{f_q}\bigg|_{|K|} = -\frac{1}{2Q_q} \left[\frac{MB\Theta}{(B|K| + N + M'\Theta)^2} d|K| + \frac{BN' X_s}{(B|K| + N' + M'\Theta)^2 R_q} d|K| \right]. \tag{11}$$

It will be seen from (11) that if the amplifier phase-shift is equal to zero and the input circuit is tuned to the oscillating frequency, the frequency stability will not be affected by variations in the amplifier gain.

For the case when $M'\Theta \ll N$, we obtain by differentiating (10) with respect to Θ the following expression:

$$\frac{df}{f_q}\bigg|_{\Theta} = \frac{M}{2Q_q (B|K| + N)} d\Theta. \tag{12}$$

Equations (11) and (12) have been obtained by means of approximate differentiation since BMNB'M'N' cannot be considered as constants. However, these formulas are in good agreement with experimental results.

In a special case when all the bridge fixed resistances ($R_2 R_3 R_4 R_5 R_6$) are equal to 1 kilohm, the value of K is sufficiently high, and R_1 is almost constant, Eqs. (10), (11), and (12) can be written in the following form:

$$\frac{f - f_q}{f_q} = \frac{1}{Q_q (|K| + 8 + 3X_s\Theta)} (8\Theta + 5X_s); \tag{13}$$

$$\frac{df}{f_q}\bigg|_{|K|} = -\frac{d|K|}{Q_q (|K| + 8 + 3X_s\Theta)^2} (8\Theta + 3.5X_s); \tag{14}$$

$$\frac{df}{f_q}\bigg|_{\Theta} = \frac{8}{Q_q (|K| + 8)} d\Theta. \tag{15}$$

Similar expressions can be obtained for other values of the bridge resistances.

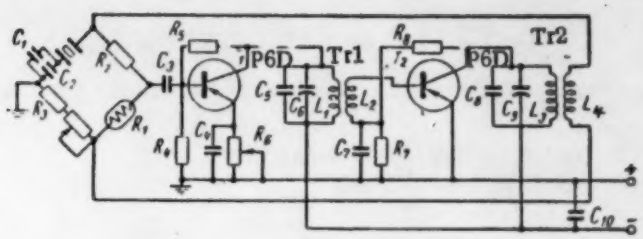

Fig. 2.

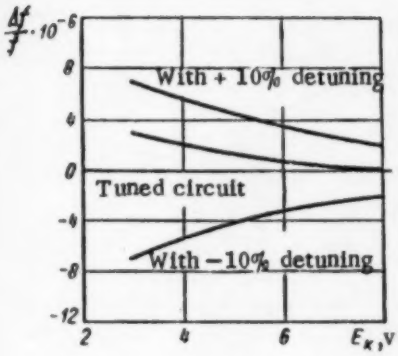

Fig. 3.

In order to illustrate the high stability of a bridge oscillator, let us analyze a circuit consisting of a two-stage amplifier and a bridge in which all the fixed resistors are equal to the resistance of the quartz crystal. Let us assume that the quartz crystal has a Q-factor of $200 \cdot 10^3$, the amplifier phase-shift is equal to zero, but can be changed in the range of ± 0.1 rad ($\sim \pm 6°$), the nominal gain is equal to 40 and can be varied in the range of $\pm 10\%$, and that $X_5 = 0.3$ kilohm. From (14) and (15) we find

$$\left.\frac{\Delta f}{f}\right|_{|K|} = \pm \frac{4}{200 \cdot 10^3 (36+8+0,09)^2} (8 \cdot 0,1 + 0,3 \cdot 3,5) = \pm 1,93 \cdot 10^{-8};$$

$$\left.\frac{\Delta f}{f}\right|_{\theta} = \pm \frac{8 \cdot 0,1}{200 \cdot 10^3 (36+8)} = \pm 9,1 \cdot 10^{-8}.$$

This example illustrates the effect of the phase fluctuations and gain variations of the amplifier on the frequency stability of the bridge oscillator.

Figure 2 shows a two-stage bridge oscillator circuit which was investigated experimentally. The amplifiers are of the common emitter type; the collector circuits are tuned to the oscillating frequency. In order to avoid spurious oscillations the transformer windings are carefully screened from each other. Working stability is provided for in the circuit. A lamp with a 3 μ platinum filament 45-48 mm long was used as a bolometer. Its resistance in the cold state is 550-600 ohm. For testing purposes type K-26 quartz crystals were used which had the following parameters: Q-factor of $200 \cdot 10^3$, $R_q = 400$ ohm, and a frequency temperature coefficient of $0.8 \cdot 10^{-6}$.

Figure 3 shows the experimentally obtained relation of the frequency instability to the supply voltage variations for the case when the tuned circuit of the first amplifier is mistuned with respect to the oscillating frequency by $\pm 10\%$.

The experimental results show that for maximum frequency stability the amplifier should have a zero phase-shift, a large phase stabilization, and a large gain, and the quartz crystal should have as high a Q-factor as possible.

The number of stages which can be used in such circuits is limited by the self-oscillations usually arising independently of the quartz crystal in amplifiers with more than two stages.

It should be noted that a high stability of a bridge oscillator circuit can be attained by relatively low frequencies, lower than 400 kc.

On the basis of our investigations and [3] it is possible to arrive at the conclusion that transistorized bridge oscillators have a higher short-term stability than similar tube oscillators, and are much more economical and reliable.

The frequency change for a $\pm 1\%$ variation in the supply voltage is about the same for both types of oscillators and equal to $\pm 3 \cdot 10^{-9}$.

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MEASUREMENT OF REFLECTION FACTORS IN NONHOMOGENEOUS COMPLEX UHF TRANSMISSION LINES

K. I. Palatov

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 36-37, December, 1960

A technique for calculating internal reflections in complex UHF transmission lines is given in a general form in [1]. Let us show its application to the problem of measuring reflection factors of two series-placed irregularities.

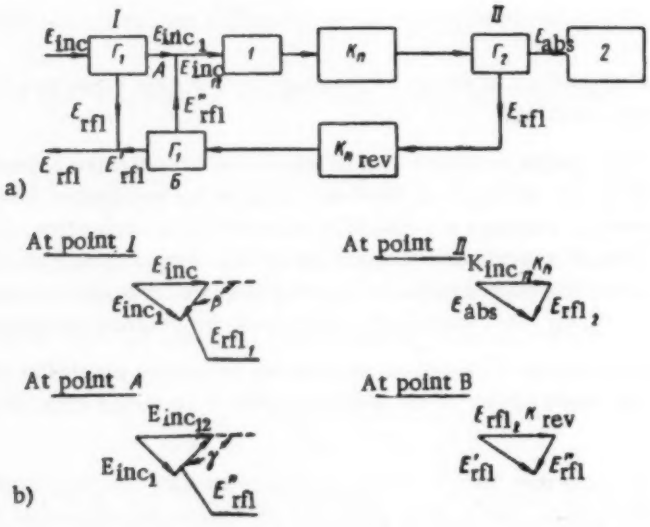

Fig. 1. a) Equivalent circuit of an equipment for measuring reflection factors of two series-placed irregularities in a UHF transmission line; 1) phase-shifter; 2) absorbing load; b) vector balance at characteristic points of the circuit in a stable state.

Similarly to the method adopted in [1], we shall represent the system with the first and second reflecting irregularities, for the purpose of accounting for the internal reflections, in the manner shown in Fig. 1, i.e., we shall separate in our mind the channels of direct and reflected waves.

By adding the vector amplitudes of direct and reflected waves at nodal points I, II, A and B we shall obtain for a steady state:

at point I

$$E_{\text{rfl}\ 1}=E_{\text{inc}}\Gamma_1;$$

$$E_{\text{inc}_1}=E_{\text{inc}}\sqrt{1+\Gamma_1^2+2\Gamma_1\cos\beta}; \tag{1}$$

at point A

$$E_{\text{inc}_{12}}=\frac{E_{\text{inc}_1}}{\sqrt{1+(K_nK_{\text{rev}\,p}\Gamma_1\Gamma_2)^2+2K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2\cos\gamma}}, \tag{2}$$

or

$$E_{\text{inc}_{12}}=\frac{E_{\text{inc}}\sqrt{1+\Gamma_1^2+2\Gamma_1\cos\beta}}{\sqrt{1+(K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2)^2+2K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2\cos\gamma}};$$

at point B

$$E'_{\text{rfl}}=\frac{E_{\text{inc}}K_nK_{n\,\text{rev}}\Gamma_2(1+\Gamma_1^2+2\Gamma_1\cos\beta)}{\sqrt{1+(K_nK_{n\,\text{rev}}\Gamma_2\Gamma_1)^2+2K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2\cos\gamma}},$$

$$E''_{\text{rfl}}=\frac{E_{\text{inc}}K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2\sqrt{1+\Gamma_1^2+2\Gamma_1\cos\beta}}{\sqrt{1+(K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2)^2+2K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2\cos\gamma}}. \tag{3}$$

It is possible to obtain, depending on the position of the phase shifter, either a maximum or a minimum value for the sum of the two reflected wave amplitudes:

$$E_{\text{rfl}\ \Sigma\,\max}=E_{\text{rfl}\ 1}+E'_{\text{rfl}}=E_{\text{inc}}\left[\Gamma_1+\right.$$

$$\left.\frac{\Gamma_1K_nK_{n\,\text{rev}}(1+\Gamma_1^2+2\Gamma_1\cos\beta)}{\sqrt{1+(K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2)^2+2K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2\cos\gamma}}\right].$$

$$E_{\text{rfl}\ \Sigma\,\min}=E_{\text{rfl}\ 1}-E_{\text{rfl}}=E_{\text{inc}}\left[\Gamma_1-\right. \tag{4}$$

$$\left.\frac{\Gamma_2K_nK_{n\,\text{rev}}(1+\Gamma_1^2+2\Gamma_1\cos\beta)}{\sqrt{1+(K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2)^2+2K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2\cos\gamma}}\right].$$

Taking this into consideration we obtain the following values for the reflection factors:

$$\Gamma_1=\frac{E_{\text{rfl}\ \Sigma\,\max}-E_{\text{refl}\,\Sigma\,\min}}{2E_{\text{inc}}}, \tag{5}$$

$$\Gamma_2=\frac{E_{\text{rfl}\ \Sigma\,\max}-E_{\text{rfl}\ \Sigma\,\min}}{2E_{\text{inc}}K_nK_{n\,\text{rev}}}\times$$

$$\frac{\sqrt{1+(K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2)^2+2K_nK_{n\,\text{rev}}\Gamma_1\Gamma_2\cos\gamma}}{1+\Gamma_1^2+2\Gamma_1\cos\beta}. \tag{6}$$

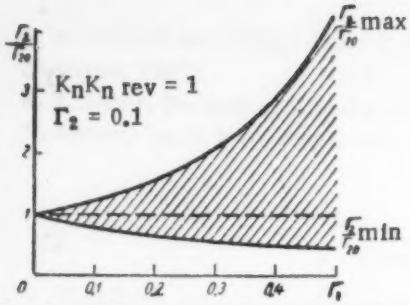

Fig. 2. Dispersion of the actual value of reflection factor Γ_2 due to phase angles β and γ and reflection factor Γ_1.

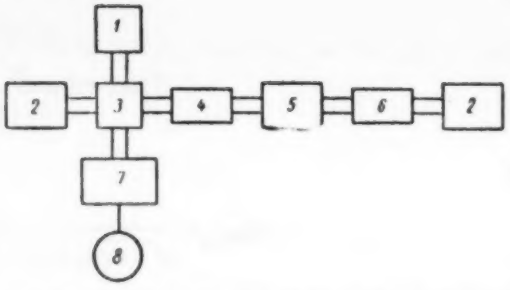

Fig. 3. Block schematic of an equipment used in practice for measuring separately the reflection factors of two series-placed irregularities in a UHF transmission line. 1) Signal generator; 2) absorbing loads; 3) twin T-junction; 4) 1st irregularity; 5) phase-shifter; 6) 2nd irregularity; 7) detector; 8) oscilloscope.

It is normally very difficult to determine the phase shifts of β and γ and, therefore, it is impossible to evaluate Γ_2 without errors which lie within a range determined by certain limiting values of cos β and cos γ. It will be seen from (6) that, depending on the values of β and γ, reflection factor Γ_2 reaches a maximum for cos $\gamma = 1$ and cos $\beta = -1$, and a minimum for cos $\gamma = -1$ and cos $\beta = 1$; taking this into consideration we have

$$\Gamma_{2\,\max} = \Gamma_{20}\frac{1 + K_n K_{n\,rev}\Gamma_1\Gamma_2}{(1-\Gamma_1)^2},$$
$$\Gamma_{2\,\min} = \Gamma_{20}\frac{1 - K_n K_{n\,rev}\Gamma_1\Gamma_2}{(1+\Gamma_1)^2}, \qquad (7)$$

where Γ_{20} is the first multiplier in (6) and represents the reflection factor Γ_2 without taking into account the internal reflections in the system under consideration.

Since in present-day practice use is made of factor Γ_{20}, the second multipliers in (6) and (7) represent the error factors due to neglecting internal reflections. The sizes of these factors for certain values of Γ_1 and Γ_2 are given in Fig. 2. It will be seen from this graph that under certain conditions the error factors may attain impermissibly high values. With a decreasing Γ_1 the error in determining Γ_2 also decreases.

The accuracy in determining Γ_1 does not depend on the presence of internal reflections in the system and is determined only by the measured values of $E_{rfl\,\Sigma\,max}$ and $E_{rfl\,\Sigma\,min}$. This fact may also be used for an accurate determination of Γ_2, if the reflecting irregularities can be interchanged in the system under test.

A circuit with a waveguide twin T-junction used for such measurements in practice is shown in Fig. 3. Well-matched dielectric fins placed in the transmission line between the two irregularities serve as phase-shifters.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. ***Some or all of this periodical literature may well be available in English translation.*** **A complete list of the cover-to-cover English translations appears at the back of this issue.**

MEASUREMENT OF REVERSE LOSSES IN FERRITE RECTIFIERS

S. S. Perel'muter

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 38-39, December, 1960

It is known that the quality of ferrite rectifiers is determined by the losses in the forward (P_f) and in the reverse (P_{rv}) directions. The forward losses usually amount to several tenths of a decibel, whereas the reverse losses exceed 10-15 db.

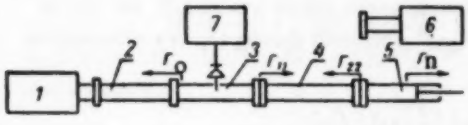
Forward losses are measured by the substitution method. Reverse losses are normally measured by means of a calibrated attenuator. In experimental work and in production of ferrite rectifiers this method is not always suitable for the following reasons. After placing the ferrite insert between the pole pieces of a permanent magnet and measuring its voltage standing wave ratio and direct loss, it is necessary to extract it and fix in the reverse direction. When the rectifier losses are high a considerable oscillator power output is required, which is not always available; and it is necessary to have an attenuator calibrated for the entire measuring frequency range.

The method sometimes used in waveguides of measuring the VSWR with a stationary plunger (dead end) is unsuitable in this case. This is due to the fact that even very small reflections from the rectifier or irregularities in the measuring line field lead to large measurement errors. These errors increase sharply with a rise in the loss of the rectifier.

A simplified block schematic of the equipment used by us and free from the above defects is shown in the figure attached. When the rectifier reverse losses are measured, the measuring line probe remains stationary and the maximum and minimum deflections of the measuring line indicator (ϵ^2_{max} and ϵ^2_{min}), obtained by moving the short-circuiting plunger, are registered, and then parameter $K = \epsilon_{max}/\epsilon_{min}$ is calculated. On the curve, obtained by calculation, the loss P_Σ introduced by the rectifier in either direction is then determined. The reverse loss equals

$$P_{rv} = P_\Sigma - P_f \approx P_\Sigma.$$

The measurements can be made rapidly and, as it will be shown later, with an error smaller than 1 db for losses of 25 db.



1) Oscillator; 2) ferrite rectifier; 3) measuring line (probe); 4) rectifier whose losses are being measured; 5) short-circuiting plunger; 6) power indicator; 7) indicator.

In order to determine the errors in this method of measuring ferrite rectifier losses let us adopt the following notations: Γ_0 is the reflection factor in the direction of the oscillator; Γ_{11} is the reflection factor of the rectifier in the forward direction; Γ_{22} is the reflection factor of the rectifier in the reverse direction; S_{12} is the transfer constant of the rectifier in the forward direction ($|S_{12}| \approx 1$); S_{21} is the transfer constant of the rectifier in the reverse direction ($|S_{21}| \ll 1$); a_0 is the amplitude of the wave transmitted by the oscillator into a matched load.

It follows from [1] that the effective reflection factor at the input of the rectifier can be written in the form

$$\Gamma_{eff} = \Gamma_{11} + \frac{S_{12}S_{21}}{1-\Gamma_{11}\Gamma_{22}}\Gamma_p = \Gamma_{11} + \frac{x}{1-\Gamma_{11}\Gamma_{22}}\Gamma_p, \quad (1)$$

where $\Gamma_p = |\Gamma_p| e^{2i\varphi}$ is the reflection coefficient from the short-circuiting plunger; $S_{12}S_{21} = x$ is the quantity which is to be determined.

The incident wave a_{inc} is determined, taking the oscillator mismatch into account, by the expression

$$a_{inc} = \frac{a_0}{1-\Gamma_0\Gamma_{eff}}. \quad (2)$$

The field at the measuring line probe can be written in the form

$$\varepsilon = a_{inc}(1+\Gamma_{eff}) = \frac{a_0}{1-\Gamma_0\left(\Gamma_{11}+\frac{x}{1-\Gamma_{11}\Gamma_{22}}\Gamma_p\right)}\left(1+\Gamma_{11}+\frac{x}{1-\Gamma_p\Gamma_{22}}\Gamma_p\right). \quad (3)$$

It will be seen from (3) that the errors of measurement can be due to the following factors: mismatching of the rectifier (for $\Gamma_{11} \neq 0$); multiple reflections between the short-circuiting plunger and the rectifier (for $\Gamma_{22} \neq 0$); changes in the incident wave due to mismatching of the oscillator (for $\Gamma_0 \neq 0$); losses in the short-circuiting plunger (for $|\Gamma_p| < 1$).

In an ideal case $\Gamma_0 = \Gamma_{11} = \Gamma_{22} = 0$, $\Gamma_p = e^{2i\varphi}$ and (3) assumes the form

$$\varepsilon = a_0(1+x\Gamma_p) = a_0(1+xe^{2i\varphi}). \quad (4)$$

Hence the maximum and minimum values of the field at the probe when the plunger is moved are

$$\varepsilon_{max} = a_0(1+x); \quad \varepsilon_{min} = a_0(1-x);$$
$$K = \frac{1+x}{1-x}. \quad (5)$$

In an ideal case the value of K coincides with that of the VSWR obtained when the loss is measured by means of a measuring line with a stationary dead end.

Whence we obtain the required value of the losses:

$$x = \frac{K-1}{K+1}. \quad (6)$$

In decibels the losses are determined in the form

$$P_\Sigma = P_f + P_{rv} = 20\lg x. \quad (7)$$

The computation curve $P_\Sigma = f(K)$ is plotted from (6) and (7).

In order to determine the maximum errors due to the above factors let us convert (3) to a simpler form.

In doing this let us remember that the reflections leading to measurement errors are small, and let us neglect the very small products $\Gamma_0\Gamma_{11}$, $\Gamma_0\Gamma_{22}x$, $\Gamma_0\Gamma_{11}x$, Γ_0x^2 and $\Gamma_0\Gamma_{22}x^2$ obtained during the transformation process.

As the result of the above we obtain $\varepsilon = a_0[1+x(\Gamma_p+\Gamma_p\Gamma_0+\Gamma_p^2\Gamma_{22})+\Gamma_{11}]$.

Let us now calculate the error due to the mismatching of the rectifier ($\Gamma_{11} \neq 0$), assuming $\Gamma_0 = \Gamma_{22}$, $|\Gamma_p| = 1$. In this case expression (8) takes the form $\varepsilon = a_0(1+x\Gamma_p+\Gamma_{11}) = a_0(1+xe^{2i\varphi}+\Gamma_{11})$. (9)

For the most unfavorable phases in the reflections from the rectifier we have

$$\varepsilon_{max} = a_0(1+x\pm|\Gamma_{11}|);$$
$$\varepsilon_{min} = a_0(1-x\pm|\Gamma_{11}|).$$

Whence the measured value of the losses x^* amounts to

$$x^* = \frac{K-1}{K+1} = \frac{x}{1\pm|\Gamma_{11}|}$$

or

$$\gamma_{\Sigma(\Gamma_{11})} = 20\lg x - 20\lg(1\pm|\Gamma_{11}|)\ (db).$$

The measurement error amounts to

$$\Delta P_{\Sigma(\Gamma_{11})} = -20 \lg (1 \pm |\Gamma_{11}|) \simeq \mp 8.69 |\Gamma_{11}| \text{ (db)}. \quad (10)$$

The error due to the mismatching of the oscillator is obtained by means of similar calculations:

$$\Delta P_{\Sigma(\Gamma_0)} = \mp 8.69 |\Gamma_0| \text{ (db)}, \quad (11)$$

as well as that due to losses in the short-circuiting plunger:

$$\Delta P_{\Sigma(\Gamma_p)} = 20 \lg |\Gamma_p| \text{ (db)}. \quad (12)$$

The losses in the plunger can only increase the measured value of the losses in the rectifier.

The errors due to reflections from the reverse side of the rectifier (for $\Gamma_{22} \neq 0$) are considerably smaller than those due to the mismatching of the rectifier on its forward side, and therefore they can be neglected.

Thus, for the most unfavorable phase relations in the reflections from the rectifier and the oscillator, the maximum error in measuring losses amounts to

$$\Delta P_{\Sigma\,\max} = 8.69(|\Gamma_0| + |\Gamma_{11}|) + 20 \lg |\Gamma_p| \text{ (db)} \quad (13)$$

and is independent of the value of the measured loss.

The error in measuring K for losses up to 25 db can be neglected.

It should be noted that, if necessary, the error due to the mismatching of the rectifier can be omitted. For this purpose it is necessary, in measuring the reversed loss, to place the measuring line probe in a position corresponding to the mean deviation of the indicator in measuring the VSWR of the rectifier itself.

The decoupling ferrite rectifier at the output of the oscillator usually provides a value of $\Gamma_0 < 0.05$; the reflection factor from the plunger normally exceeds 0.97-0.98 and hence the errors due to the mismatching of the oscillator and losses in the plunger become insignificant.

In the above method the probe remains stationary and, hence, the manufacturing quality of the measuring lines does not affect the accuracy of measurement. This makes it possible to measure very small values of parameter K (of the order of 1.02), i.e., large values of reversed losses (of the order of 40 db). The accuracy in measuring such values of K can be raised, if the mean deviation of the indicator is first compensated and then its sensitivity is raised by a large amount. Instead of the measuring line it is possible to use a probe head, which is considerably simpler and cheaper than a line [2]. This is particularly important for measurements in the millimeter range.

In certain instances it may be useful to apply a phase shifter with a dead end instead of a short-circuiting plunger.

If the characteristic of the crystal detector in the operating range differs considerably from a quadratic form, the relation $P_\Sigma = f(K)$ can be plotted from the loss introduced by a calibrated attenuator (at any single frequency in the range). It should be noted that in this instance $P_\Sigma = 2P_{attn}$.

This method can be used not only for the measurement of ferrite rectifiers, but also of other, irreversible devices (for instance, circulators) and certain UHF channels.

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RADIATION MEASUREMENTS

MEASURING THE GAMMA CONSTANT OF RADIUM

K. K. Aglintsev, G. P. Ostromukhova, and E. A. Khol'nova

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The gamma or ionization constant is an important dosimetric characteristic of any γ-radiating isotope; it is numerically equal to the dose rate in roentgens per hour at a distance of 1 cm from a point source of radiation of 1 mC preparation of a given isotope [1]. The value of the γ-constant of radium, which remains an important reference substance, is of particular interest for practical dosimetry. The determination of this value has attracted the attention of experimenters over a number of years; however, the results thus obtained differ from each other.

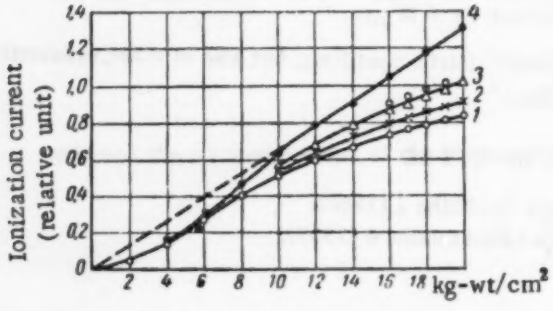
Below we give the technique used and the results obtained in determining the γ-constant of radium by the D. I. Mendeleev VNIIM (All-Union Scientific Research Institute of Metrology).

The value of the γ-constant was determined by measuring the dose rate and activity of the same preparation, i.e.,

$$\Gamma\,(\mathrm{Ra}) = \frac{P \cdot 3600}{Af}, \qquad (1)$$

where P is the dose rate at a distance of 1 cm from the preparation, r/sec; A is the activity of the preparation, mC; f is a correcting factor which takes into account the self-absorption of the radiation in the preparation and the absorption in its sheathing.

In order to eliminate the correction for self-absorption of γ-radiations by the source, a correction which cannot be determined with sufficient accuracy and depends on certain indeterminate factors (random distribution of the radium salt in the ampoule), we used in our measurements, in place of radium, preparations of radon, which are in radioactive equilibrium with the short-life products of their decay.



It is known that γ-radiations of balanced preparations of radium and radon are determined by their derivatives RaB and RaC and are, therefore, practically identical. The line pertaining to the spectrum of the radium itself is so soft and weak that it is absorbed by the wall of the sheathing and does not take part in the general ionization. Since radon is a gas the self-absorption in it is negligibly small. Therefore in (1) it is only necessary to introduce a correction for the absorption in the wall of the ampoule.

Measurement of the radon preparation dose rate P without additional platinum filtration was made by means of a reference equipment with a free-air chamber. Moreover, the correction factors for the penetration of radiation over the edges of the diaphragm, for the attenuation of radiation in the aluminum window of the tank, for scattered radiation and the displacement of the effective absorption region of γ-quanta with respect to the measuring volume [2] were calculated by taking into

consideration the relative intensity of the γ -quanta of the radium spectrum [3] and found to be equal to: K_1 = = 0.97, K_2 = 0.895, K_3 = 0.985 (for pressures of 16-20 kg-wt/cm²), K_4 = 0.996 respectively.

The linear attenuation constant of γ -radiations of radium in air was found experimentally. For this purpose γ -radiations of radium were measured for different positions of the chamber in the tank and at varying air pressures. The measurement results are shown in the figure attached. Curves 1 and 2 give the relation of the ionization current (for E = 302 v/cm, t = 0°C) to the air pressure in the chamber; curve 1 was obtained for a distance between the input window of the tank and the center of the measuring electrode equal to 134.6 cm; curve 2 for 74.6 cm. The difference between currents 1 and 2 represents the attenuation of γ -radiations of radium in air for different pressures. The mean value of the linear attenuation constant (for 14-20 kg-wt/cm² at t = 20°C) was $\mu = 8.5 \cdot 10^{-5}$ cm^{-1}. By correcting the current values (curves 1 and 2) for the attenuation in the air, calculated for the measured value of μ, curve 3 was obtained. Curve 4 shows the relation between the saturation current, obtained by extrapolating by the Jaffe-Zanstra [4] method, and pressure taking into consideration corrections for scattered radiations.

It follows from the graph (curve 4) that starting with chamber air pressures of 14 kg-wt/cm² the saturation current becomes proportional to pressure. This indicates a complete utilization of the ionizing property of electrons which arise in the chamber when γ -quanta are absorbed.

The table shows the probable errors of quantities which enter into the calculations of the dose rate.

On the basis of all the errors listed in the table the error in determining the dose rate amounts to ±2%

The activity of the radon preparations was determined by the calorimetric method. For this purpose two differential static-type double calorimeters were used: one solid γ -calorimeter, and the other a thin-walled α -calorimeter.

The γ -calorimeter for radium measurements of a type already in use at the VNIIM consists of two lead 140 mm diameter balls, placed in a thermostat and interconnected by a system of thermocouples. The measured preparation is placed inside one of the balls, which heats up owing to its absorption of α, β and γ -rays radiated by the preparation. The difference in temperature between the calorimeter balls, measured by means of a thermopile, serves as a measure of the thermal power of the source. Having calibrated the calorimeter in watts by means of a heating coil, it is possible to determine the radiation power of any radioactive preparation by measuring the difference of temperature it produces.

In order to obtain from the thermal power of the radon preparation, measured by means of the γ -calorimeter, the activity of the preparation, it is necessary to know the total energy E produced by the disintegration of one radon nucleus. In doing this, it is necessary to take into account all the radon short-life derivatives, up to RaC" inclusive, which are in radioactive equilibrium with radon. The value of E calculated from the known energies and absolute outputs of various types of balanced radon radiations is equal to 22.277 Mev/decay, i.e., the full thermal effect of 1 mC of radon amounts to $q_{full} = 132.1 \cdot 10^{-6}$ w/mC.

Even in such a massive calorimeter as the one we used (the effective thickness of absorption amounts to 6.5 cm Pb) the hard γ -rays of radium are not completely absorbed. A calculation of the absorption of γ -rays of various energies in a spherical absorber has shown that the above calorimeter absorbs 96.2% of all the radium γ -radiation energy. Taking this into account, the thermal effect of 1 mC of radon in the γ -calorimeter was taken to be equal to $q_\gamma = 131.6 \cdot 10^{-6}$ w/mC.

By dividing the thermal power of the radon preparation, as measured on the γ -calorimeter, by q_γ we find the activity of the preparation in mC. The error in the activity of the radon preparation established by means of the γ -calorimeter did not exceed ± 1.2%.

The activity of radon preparations was also measured α -calorimeter equipment. In an α -calorimeter the heat receivers consist of thin-walled copper beakers (0.2 mm Cu) and the measured thermal effect is only due to the easily absorbed, mainly α -particles; γ -radiations almost completely pass through the calorimeter. Under these conditions the thermal effect of 1 mC of radon was taken to be equal to $q_{\alpha+\beta} = 121.6 \cdot 10^{-6}$ w/mC. The error with which it was possible to establish the activity of radon preparations by means of an α -calorimeter did not exceed ± 0.8%.

Measured quantity	Probable error, %
Saturation current	±1.6
Measuring volume	±0.1
Air pressure	±0.4
Correction factor for air temperature in the chamber	±0.1
Distance between the center of the preparation and the plane of the restricting diaphragm	±0.1
Correction factor for the penetration of radiations through the edges of the diaphragm	±0.7
Correction factor for the attenuation of radiations by the air	±0.4
Correction factor for the attenuation of radiation in the tank input window	±0.1
Correction factor for the scatter of radiations	±0.2
Correction factor for the displacement of the effective region of γ-quanta absorption	±0.2

By measuring the radon preparation first on the γ-calorimeter and then on the α-calorimeter we always obtained activity values which did not differ by more than 1%.

As the result of measuring the dose rate P and activity A of various radon preparations the mean value of the γ-constant of radium for unfiltered radiations was calculated and found to be equal to (8.97 ±0.18) r/hr·mC··cm.

A comparison of the γ-radiation measurements of Ra and Co^{60} showed that the ratio of the Co^{60} and Ra γ-constants amounts to $\Gamma(Co/Ra) = 1.45$ which, in the limits of the error of measurement, agrees with the value of 1.43 given in [5].

The experimental data provided in [6] gives the attenuation of radium γ-radiations in a 0.5 mm platinum screen as 10% with an error of ±2%. Taking into consideration these data, we obtain the value of the γ-constant of radium filtered through a 0.5 mm platinum plate, equal to 8.1 r/hr·mC·cm.

Most of the work in determining the γ-constant of radium is based on measurements of the dose rate made by means of thimble chambers whose construction meets Bragg-Gray's conditions. However, in measuring doses by means of thimble chambers it is necessary to know the ratio of the stopping powers S_z/S_{air} of the chamber wall and air.

It is stated in [7] that the error in determining S_z/S_{air} is less than ±1%. We think it is somewhat larger. Thus, for instance, the ratios of stopping powers of graphite and air given in [8, 9], which can also be used for calculating the dose rate in thimble chambers, differ from each other by ±2%.

According to the theory cited in [10] the stopping power depends not only on the energy of electrons and the ordinal number of the substance, but also on the value of the energy required by the electron to cross the air space. Thus, the value of the stopping power depends on the size of the chamber cavity. Moreover, the stopping power depends on the state of aggregation of the substance; the correction for the so-called density effect amounts to 1-2% [11].

Obviously, all the measurements made with thimble chambers before the above theories became known need to be revised.

The second substantial source for the uncertainty in γ-radiation measurements made by means of thimble chambers in rays with beam irising is the effect produced by the conditions of irising on the measurements [12]. Measurements obtained by the same chamber may differ for different aperture angles of the beam. This effect is particularly marked (up to 15-20%) when the distance between the preparation and the chamber is less than 50-70 cm. By raising the distance to 3-4 m the readings of the instrument become less dependent on the variations in the diameter of the beam cross section and approach the readings of a thimble chamber to those obtained in a free-air chamber.

Moreover, a technique has not yet been established for calculating the error in a thimble chamber due to scattered radiations in air, which produce additional ionization in the chamber.

Taking all the above facts into consideration it appears to us that the γ-radiation dose-rate measurements made in thimble chambers are less accurate than those made in free-air chambers.

For comparison purposes we give below measurements of the γ-constant of radium obtained with a 0.5 mm platinum filter by various experiments. Since in literature the data on the γ-constant of radium is given in terms of 1 mg, we corrected the values obtained by us, assuming the number of disintegrations in 1 mg of radium to be $3.68 \cdot 10^7$.

According to our data obtained in a free-air chamber, this value amounts to 8.04 r/hr·mg·cm; other experimenters' figures are: for a cylindrical graphite chamber – 8.26 [13], for a free-air chamber – 8.16 [14], for a cylindrical polystyrene chamber – 8.4 r/hr·mg·cm [15].

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RADIUM-MESOTHORIUM-BERYLLIUM SOURCE OF NEUTRONS

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Side by side with using intensive steady-state sources of neutrons for many purely scientific and applied investigations, neutron sources obtained by means of natural α-radiations are still widely used. The majority of such sources are prepared by mixing ground salts of one of the α-active substances X_α (for instance Ra, Ac, Po and others) with powdered metallic beryllium. In the case of Po^{210}, which possesses a high specific activity, biscuit type sources (sandwich sources) are made, in which the radioactive substance is applied in a thin layer on the surface of a beryllium disc.

For the (X_α + Be)-neutron sources in addition to the total number of neutrons radiated in a unit of time it is also interesting to know the neutron output, which is normally determined as the ratio of the number of radiated neutrons per second to the activity of the radioactive substance of the source measured in curie units. The output of the X_α + Be type sources depends both on the radioactive substance used in them and on the method of preparing

them (on the degree to which the radioactive substance and beryllium have been pulverized, on the ratio of their weights, degree of homogeneity in mixing, etc).

Much has been written about the neutron output, the spectral composition of the radiated neutrons and other characteristics of radium-beryllium sources, which are widely used in science and technology. However, in addition to neutron sources which use pure radium one also often comes across sources which use radium-mesothorium-beryllium. Such sources are made with so-called mixed preparations, which in turn are obtained from urano-thorium ores and contain a large amount (30-45%) of mesothorium.

Mesothorium (MsThI) is radium isotope and, therefore, can hardly be separated from radium by ordinary chemical means. The half-life of mesothorium, which radiates mainly soft β-rays, is equal to 6.7 years.

In time such mixed preparations accumulate radiothorium (RdTh) with its short-life derivatives ThX, Tn, ThA, ThB, ThC, ThC' and ThC". The majority of these derived products and the radiothorium are α-radiators, and the energy of the radiated α-particles is sufficient to form beryllium neutrons. It is obvious that the number of neutrons radiated by such radium-mesothorium-beryllium sources will be a function of time, determined by the original ratio of radium to mesothorium, their half-life and the output of reaction $Be^9 (\alpha, n) C^{12}$ for separate isotopes in the radium and thorium series. Since the energy spectra of α-particles of radiothorium and its derivatives are on an average a little harder than the α-spectra of the radium series, one should expect the total neutron output of a (RdTh + Be) source to be a little higher than that of a (Ra + Be) source. By using the known relationship between the neutron output η and the energy of α-particles which bombard a thick target, and the value of the energy and intensity of separate α-lines [1], it is possible to calculate the expected output ratio of neutrons from the (RdTh + Be) and (Ra + Be) type sources. The output ratio in question $K = \frac{\eta\,(\text{RdTh} + \text{Be})}{\eta\,(\text{Ra} + \text{Be})}$ was calculated to be approximately 1.6. On the basis of the relation between output of reaction (α, n) of beryllium and the energy of α-particles given in [2] it was found that K = 1.57, but from the data given in [3] K was calculated to be 1.66. If K is known, it is possible, on the basis of the known half-life of mesothorium and radiothorium and the known initial ratio of thorium to mesothorium in the source, to calculate the expected variation in the number of neutrons radiated per sec in a radium-mesothorium-beryllium source with respect to time, i.e., with respect to the "age" of the source.

Below we give the results obtained during several years of measurements of the number of neutrons radiated per second by such sources, and provide a comparison with calculations.

The 84NRM source was made in July 1949 from a radium-mesothorium preparation with a known sealing date (January, 1948).

On the basis of the measurements of its radium γ-equivalent and calorimetric measurements of its thermal effect it was calculated that at the instant the preparation was sealed it contained 198 mC of radium and 112 mg-eq-radium of mesothorium, and, hence, the initial content of radium and mesothorium in the preparation was 64 and 36% respectively.

Calculated and Experimental Values of the Radium γ-Equivalent J and the Relative Number of Radiated Neutrons A_n for a Radium-Mesothorium-Beryllium Neutron Source

Date of measurements	Number of years which passed between the sealing and measuring date t	Calculated composition of the source at various dates						Radium γ-equivalent, mg-eq-radium				Relative number of neutrons A_n				Thermal effect Q, cal/hr	
		Ra, mC	MsTh		τ_t	RdTh		J calc.	J expr.	$\frac{J}{J_0}$ calc.	$\frac{J}{J_0}$ expr.	A_n calc.	A_n expr.	$\frac{A_n}{A_{n0}}$ calc.	$\frac{A_n}{A_{n0}}$ expr.		
			mg-eq-radium	mC		mC	mg-eq-radium										
Jan. 3, 1948	0	198.0	112	213	0	–	–	310	–	1.00	–	198	–	1.00	–	–	–
Jan. 1, 1949	1.00	197.8	101	193	0.321	62.0	48.1	347	346	1.12	1.12[1]	297	–	1.50	–	–	–
Oct. 10, 1949	1.77	197.8	93.0	177	0.516	91.3	70.8	362	362	1.17	1.17	345	–	1.74	–	–	–
Dec. 10, 1949	1.95	197.8	91.4	174	0.568	98.8	76.6	366	–	1.18	–	357	334	1.81	1.81[1]	–	–
Dec. 10, 1953	5.95	197.5	60.5	115	1.095	125.9	97.6	356	352	1.15	1.14	403	375	2.04	2.03	48.7	48.8
Feb. 10, 1959	11.1	197.0	35.7	68.0	1.316	89.5	69 4	302	305	0.97	0.98	348	328	1.76	1.78	43.3	44.0

[1] In view of the fact that to date no experimental data for these values is obtainable, they were replaced by calculated values of $J/J_0 = 1.12$ and $A_n/A_{n0} = 1.81$ respectively.

For these calculations we used the relations, which were previously obtained experimentally [4], between the activity and the radium γ-equivalent for mesothorium and radiothorium which existed for the conditions of ionization measurements used by us (a five-millimeter lead cylindrical filter round the source and a standard thin-walled liter electrometer SG-1M chamber).

1 mC of MsTh = 0.525 mg-eq-radium,
1 mC RdTh = 0.775 mg-eq-radium.

Moreover, it was taken into account that the two-millimeter copper walls of the neutron source container absorbed ~7% of its γ-radiations. The self-absorption of γ-rays in radium and beryllium and the losses known from ionization measurements, and related with the methods of producing the source, were also taken into account.

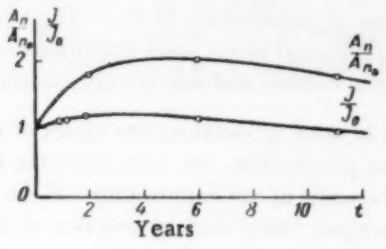

Fig. 1.

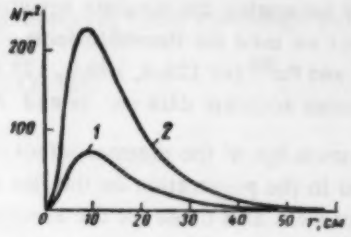

Fig. 2.

The table contains the results of measurements of the content of radium, mesothorium and radiothorium in the source and its total radium γ-equivalent J for the instant of neutron and γ-radiations. In addition to the above-mentioned relations between the activity and the radium γ-equivalents of RdTh and MsTh, we also used the data [4] of the ratio T_t of the number of atoms of these isotopes disintegrating per unit time in the radium-mesothorium preparations of different "ages":

$$T_t = \frac{(\lambda N_t)\ \text{Rd Th}}{(\lambda N_t)\ \text{Ms Th}},$$

where λ and N_t are the constants of disintegration and the number of atoms at the time the corresponding isotopes were used.

Half-lines of RdTh and MsTh were taken to be 1.9 and 6.7 years respectively.

The table also contains data on the number of neutrons A_n radiated per second, in which the number of neutrons radiated by 1 mC of radium mixed with an infinitely large quantity of powdered beryllium was taken as a unit. These values of A_n were calculated for K = 1.6.

The last two columns of the table also give the calorimetric measurements of the thermal effect Q of the radioactive radiations of the preparation and the calculated values of this quantity.

Figure 1 provides a graphic representation of the expected variation in the number of neutrons A_n and the radium γ-equivalent J calculated on the basis of the above mentioned initial content of radium and mesothorium in the source (64 and 36% respectively) and of K = 1.6. It will be seen from Fig. 1 that the experimental points lie accurately on the calculated curves.

In determining the number of neutrons radiated by the source the method of comparing the integral distribution of neutrons from that source moderated in water with a reference radium-beryllium source [5] was used. Measurements were made in a 300-liter vessel filled with water. The slow neutrons were detected by a standard boron chamber KN-14 and a small thimble chamber. The efficiency of these chambers differed by about one order, thus making it possible to measure over a wide range of "neutron activity" of the source. By comparing the areas under the curves thus obtained the relative number of neutrons A_n of the source was determined for each measurement. Figure 2 shows the spatial distribution of slow neutrons in water from source Ra + Be (curve 1) and from source RaMsTh + Be (curve 2). Since the distribution depends on the energy spectrum of fast neutrons, it

becomes obvious from curves 1 and 2 that the mean energies of the spectra of radiated neutrons of sources Ra + Be and RdTh + Be are about the same.

The experimental values of A_n are corrected for the "concentration" coefficient Y of the reference source Ra + Be and the measured source [$Y = M_1/(M_1 + M_2)$, where M_1 is the weight of beryllium, M_2 is the weight of other components in the source].

The value of this coefficient for the reference source was found to be equal to 0.967, and for the measured source, 0.808. Account is also taken of the increased number of neutrons due to the accumulation of polonium in radium.

The calorimetric measurements, as we have already stated, served to check the calculated values of activity of radioactive sources. The double static differential calorimeter used for these measurements is also employed for measuring the absolute activity of various radioactive preparations [6]. In calculating the expected thermal effect we used the thermaleffects of 1 curie α- and β-radiations of preparations of equal weight of Ra, RdTh, MsTh and Po^{210} (of 129.3, 170.3, 173.0 and 27.54 cal/hr·C respectively) which were calculated on the basis of the most accurate data on α- and β-radiation of isotopes in the radium and mesothorium series [1].

The knowledge of the thermal effect of polonium was necessary in order to evaluate the effect of its accumulation in the preparation on the rise in the thermal effect of the preparation. In calculating the value of Q, corrections were also made for the absorption of γ-radiations in the walls of the calorimeter and the source itself. From the above table it will be seen that the calculated values agree fairly well, at any rate within the limits of experimental errors, with the experimentally obtained values of Q. This confirmed the originally estimated content of radium and mesothorium in the source.

An analysis of the table shows that the calculated values of A_n are fairly close to the experimental ones. The small discrepancies of the order of 5-7% may be due to imperfect preparation of the source, which made the values of the output η smaller than the optimum for all the α-radiations contained in the source. On the other hand, it is also possible to assume that the actual value of the coefficient $K = \frac{\eta\ (RdTh + Be)}{\eta\ (Ra + Be)}$, used in our calculations of the "neutron activity," was a little smaller than 1.6 which we assumed. Experimental data agree better with a value of K equal to 1.4. Yet, this provides a worse agreement in the variations of the "neutron activity" with the experimental data. This is one of the reasons which make the first assumption seem to be more likely. At any rate the preparation of a neutron source made of pure RdTh for checking experimentally the value of K is of considerable interest.

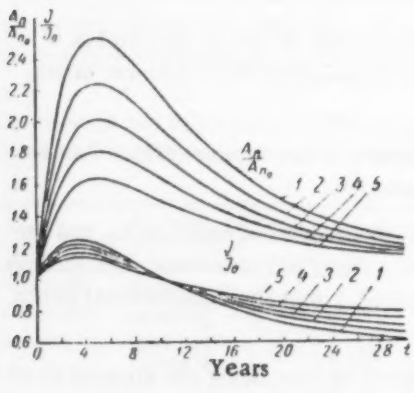

Fig. 3.

Figure 3 shows calculated curves which make it possible to determine the number of neutrons A_n radiated per second and the radium γ-equivalent J of the radium-mesothorium preparation for various initial contents of radium and mesothorium in the source (55 and 45% – curve 1; 60 and 40% – curve 2; 65 and 35% – curve 3; 70 and 30% – curve 4; 75 and 25% – curve 5 respectively) at any time t between 0 and 30 years. These curves, it seems to us, can serve a useful purpose when radium-mesothorium sources of neutrons are applied for a long time under laboratory and especially commercial conditions.

Providing the initial ratings are available (the initial number A_n of neutrons radiated per second and the composition of the preparation), it is possible to determine fairly accurately by means of these curves the "neutron activity" at any given time.

It will also be seen from the curves that the initial relative content of Ra and MsTh in the source can be determined from A_n measurements. In fact it will be seen from Fig. 3 that the value of A_n is affected much more by the initial relative content of Ra and MsTh in the preparation than by the variations in its radium γ-equivalent. With the knowledge of A_{n_0} and having measured A_n over 2-4 years of operation it is possible to determine the relation of Ra to MsTh in the source with an error of approximately 1%. This new method of determining the composition of mixed preparations made from urano-thorium ores is more accurate than the previously used ionization and calorimetric methods.

SUMMARY

On the basis of the above experimental and calculated data a graph was plotted which makes it possible to determine the number of neutrons radiated per unit time by a source made of a mixture of radium-mesothorium with beryllium, and the radium γ-equivalent of such a source with respect to time, for different initial content of radium and mesothorium in the source.

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DYNAMIC ERROR IN REGISTERING THE POSITION OF AN OBJECT BY MEANS OF RADIOMETRIC RELAYS

K. S. Klempner and A. G. Vasil'ev

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 46-47, December, 1960

The problem of a dynamic error in registering the position of an object by means of radiometric relays has not as yet been studied, but it represents considerable interest, especially in the cases when the relay is used in automatic control circuits; for instance, in measuring the position of the level of liquids or loose materials, for constructing a contactless end of travel switch, etc.

The dynamic error in registering the position of the object depends to a great extent on the inertia of the radiometric relay due to the speed of transient processes in the RC integrator, on the dimensions of the sensitive surface of the detector, on the relative positions of the source and the detector, and on the speed of the moving object.

Without changing the generality of reasoning let us examine a single-position level meter (Fig. 1). Let a beam of parallel rays from the source of nuclear radiation fall on the detector. Let the length of the detector's sensitive surface in the direction of the object's movement be l, the rate of radiation attenuation in the absorber be sufficiently large, and the speed of the level movement be constant and equal to v. We shall examine the case of $v > 0$, but it is obvious that the case of $v < 0$ is identical. As a reference surface we shall arbitrarily take a plane parallel to the surface of the object and passing through the uppermost point of the detector. Then the change in the position of the object from the instant it passes through the reference surface to the instant the relay operates is, obviously, equal to the dynamic error of measurement x_0 (in the chosen reference system, x is the instantaneous value of the object's co-ordinate).

In order to calculate x_0 it is necessary to know the function $U(x)$, where U is both the potential at the output of the integrator relay and the potential U_{0-1} when the relay passes from the condition with an absorber in the line of control (position 0) to condition 1 (no absorber in the line of control). In order to find function $U(x)$ let us first find an expression for function $U(t)$, and then by substituting the variables pass to finding the required values. From [1] function $U(t)$ can be represented in the form

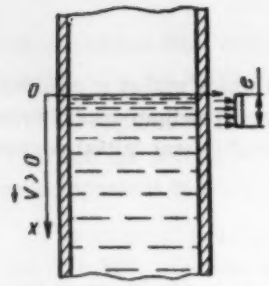

Fig. 1.

$$U(t)=k\Delta U_0 v e^{-\frac{t}{RC}}\int_0^t e^{\frac{\tau}{RC}}\,n(\tau)\,d\tau, \tag{1}$$

where ΔU_0 is increment of the potential at the integrator output when one pulse is received; k is mean speed of counting over 1 cm of the detector's surface in the direction of object movement.

Counting speed as a function of time $n(\tau)$ is determined by the expression

$$n(\tau)=\begin{cases} kvt, 0<t<\dfrac{l}{v} \\ n, \quad t>\dfrac{l}{v}. \end{cases} \tag{2}$$

By integrating (1) and taking into account (2) we obtain, after several simple transformations,

$$U(x)=\frac{\Delta U_0 nRCx}{l}\left[1-\frac{RCv}{x}\left(1-e^{-\frac{x}{vRC}}\right)\right] \text{ for } x<l. \tag{3}$$

$$U(x)=\Delta U_0 nRC\left[1-\frac{RCv}{l}\left(1-e^{-\frac{l}{vRC}}\right)e^{-\frac{x-l}{vRC}}\right] \text{for } x>l. \tag{4}$$

The above equations make it possible to find U(x) for any specific parameter values of the device.

For v = 0 the potential is determined solely by (3), which in this case can be reduced to the form

$$U(x)=\frac{\Delta U_0 nRCx}{l}. \tag{5}$$

For the other limiting condition v = ∞ the potential is determined solely by (4). In this case the second term in (4) is represented by an indefinite expression of the form $\infty \cdot 0$. By solving the indefinite expression we obtain

$$U(x)=\Delta U_0 nRC\left(1-e^{-\frac{x-l}{vRC}}\right)\equiv 0. \tag{6}$$

By plotting a family of curves for the values of $\Delta U_0 nRC = U_1 = 1$, $l = 10$ and certain values of v over the whole possible range of speed variations, when the value of the transition potential U_{0-1} is given as $0.5U_1$, we shall find that for very low speeds of the object's movement the potential at the output of the RC integrator varies linearly with respect to the variable coordinates. The dynamic error is then sufficiently small ($x_0 < l$). With an increasing speed of the object's displacement the lag rises and the dynamic error increases ($x_0 > l$). And finally, for very high speeds of the object's displacement the dynamic error tends to infinity ($x_0 \gg l$).

From the above it follows that in certain cases when the error of measurement is large and the speed of the object's displacement is constant, the reference surface should be placed at a certain distance from the given place of control.

On the other hand, in cases when the speed of the object's movement is not constant it is necessary to relate the error of measurement to the speed of movement. These evaluations can be easily arrived at either analytically or by solving Eqs. (3) and (4) with respect to $x = x_0$.

A solution of (4) is

$$x_0=vRC\ln\frac{vRC}{l}\cdot\frac{U_1}{U_1-U_{0-1}}\left(e^{\frac{l}{vRC}}-1\right) \text{ for } x_0>l. \tag{7}$$

Equation (3) cannot, unfortunately, be solved in simple functions with respect to $\underline{x}$. An approximate solution can be obtained by expanding $l^{-x/vRC}$ into a series in the powers of x/vRC. By taking the first three terms of the expansion we have

$$x_0 = \left(\frac{U_{0-1}\,2RCvl}{U_1}\right)^{\frac{1}{2}} \text{ for } x_0 < l. \tag{8}$$

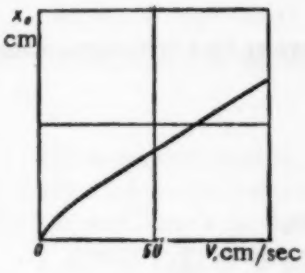

Fig. 2.

Figure 2 represents a relation of the form of $x_0 = f(v)$ plotted from (7) and (8). The above relation is plotted for l = 10 cm, RC = 1, U_{0-1} = 0.5 U_1. There is no difficulty in plotting a similar graph for any other set of parameter values of this device.

It is obvious that when the detector's time of overlapping is small as compared with the integrator's time constant, i.e., $l \ll RCv$, the relation $x_0 = f(v)$ is represented practically over the whole range of x_0 values by (7) which in this instance can be represented, after solving the indeterminate expression $\infty \cdot 0$, by the following equation:

$$x_0 = vRC \ln \frac{U_1}{U_1 - U_{0-1}}. \tag{9}$$

It will be easily seen [2] that this result can be written in a somewhat different form:

$$x_0 = v\Theta_{0-1}, \tag{10}$$

where Θ_{0-1} is the relay operating time from the instant the detector is irradiated.

Thus, in the simplest instance, when the detector dimensions can be neglected, the value of x_0 is determined by the product of the object's speed of movement and the relay's operating time.

Assuming that the rate of attenuation of radiations in the controlled object is finite and taking advantage of the results obtained in [2], we can generalize these results for the case when the controlled object crosses the reference plane in the upward direction:

$$x_{01} = vRC \ln \frac{U_1 - U_0}{U_{1-0} - U_0} \quad \text{(absorber in);} \tag{11}$$

$$x_{02} = vRC \ln \frac{U_1 - U_0}{U_1 - U_{0-1}} \quad \text{(absorber out).} \tag{12}$$

It will be seen from (11) and (12) that the dynamic error in registering the position of the object when the absorber is introduced or withdrawn is different as a rule. The values of x_{01} and x_{02} are equal when

$$\frac{U_1 + U_0}{2} = \frac{U_{0-1} + U_{1-0}}{2}. \tag{13}$$

If the time constant of the integrator is considerably smaller than the operating time and time of releasing the output electromagnetic relay, Eqs. (11) and (12) become respectively

$$\begin{aligned} x_{01} &= vt_{rls}; \\ x_{02} &= vt_{opr}. \end{aligned} \tag{14}$$

In all the expressions quoted above U and Θ have random values. Hence the value of x_0 has a statistical nature.

The maximum dynamic error in measuring the position of the object can be evaluated normally by $3\sqrt{x_0}$. More accurate statistical evaluations are possible [3] but hardly advisable, since the total error of measurement

depends on the irregularity in the object's speed of displacement and other factors which as a rule it is difficult to evaluate.

SUMMARY

The maximum dynamic error in registering the position of the object by means of radiometric relays is attained in a device with a low integrator time constant.

However, a low integrator time constant leads to statistical errors of measurement which can only be decreased by raising the activity of the emitter. In the cases when it is possible to displace the measuring device with respect to the reference plane it is better to use a relay with a large integrator time constant; naturally, the statistical error of measurement is then decreased.

The above analysis can be used for computing the dynamic accuracy and devices for a continuous measurement of levels.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

MEASURING THE DENSITY OF MELTS

B. A. Glagovskii

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 48-50, December, 1960

The areometers used in industry cannot measure the density of smelts at high temperatures, since smelts are inside thick-walled containers (pots, crucibles, etc.) placed in ovens or thermostats. In order to measure density in such cases a special areometer is required.

Below we describe an instrument we developed for this purpose by converting a special level meter which served to measure the level of smelts at high temperatures in the manner described in detail in [1].

New elements 7-12 have been added to the level meter (Fig. 1).

The density is determined by weighing the smelt and measuring its volume.

The volume is measured by means of the level meter [1], since the volume of a smelt in a container of a regular shape is determined by its level. The calibrating graph contains, in addition to the level curve, also a curve representing $V = f(l)$, where l is the reading of the level meter and V is the volume of the smelt.

Thus, the bending of the level meter measures both the level and the volume of the smelt. The level meter calibration remains the same (over the whole measuring range).

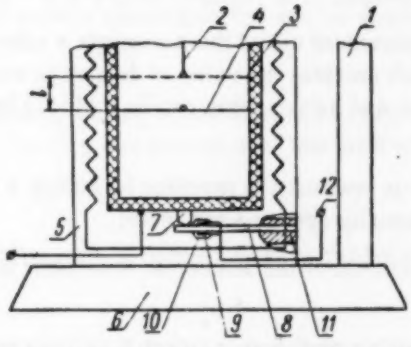

Fig. 1. Schematic of an areometer for measuring the density of smelts. 1) Frame which supports the measuring plate with transducers glued to its surface (the schematic does not show the plate or the transducers); 2) pin fixed to the free end of the measuring plate; 3) container which carries the smelt; 4) smelt whose density is being measured; 5) oven; 6) base; 7) peg; 8) cantilever beam; 9) strain-gauge transducers; 10) casings covering the transducers; 11) support to which beam 8 is fixed; 12) terminals to which the strain-gauge 9 leads are fixed.

The measured volume is weighed by means of strain-gauge transducers 9, connected in a bridge circuit. The above transducers (R'_{p1} and R'_{p2} in Fig. 2 and 4) are connected to adjacent arms of the bridge, thus eliminating the temperature errors due to the possible heating of the beam.

A change in the weight of the smelt varies the bending of beam 8 (Fig. 1), which is registered on an

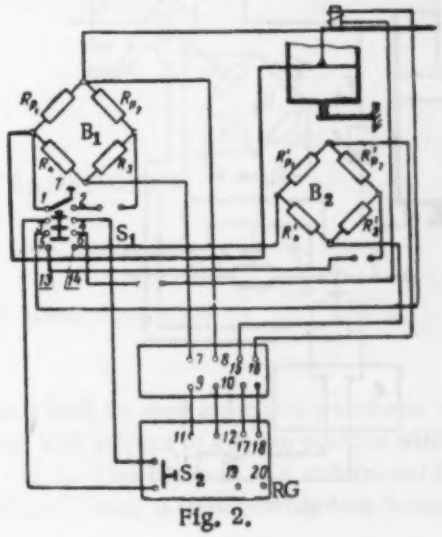

Fig. 2.

oscillograph or recorder. The signal from the weighing device passes through an amplifier similar to that used in the level meter [1], and mounted in the same casing as the latter.

The scales are calibrated by filling the crucible with known weights. From the data thus obtained a graph of $p = f(P)$ is plotted, where p is the output parameter of the circuit (for instance, output current), and P is the weight of the load in the container (crucible), which corresponds to a definite strain in the beam of the scales.

The scale beam provides, in the measuring range of the level meter [1], sufficiently large strains for measuring the density of practically any liquid (with a specific gravity from 0.6 to 14).

Both the areometer and the level meter [1] are made in two versions: with manual and automatic control.

Figure 2 shows the electrical circuit of an areometer with manual control.

The areometer operates in the following manner: by pressing tumbler switch T supplies are connected to bridge B_1 of the volumeter. Push-button switch S_2 starts the chart-propelling mechanism of the oscillograph (or recorder).

Zero lines 1 and 7 of the reference oscillograph galvanometer (Fig. 3) are drawn across the film (paper). Zero line 1 corresponds to the unstressed condition of the volumeter measuring-plate [1].

The reference oscillograph galvanometer line corresponds to the "zero" of the scales; the reference oscillograph galvanometer (contacts 19-20 in Fig. 2) is not connected to the circuit.

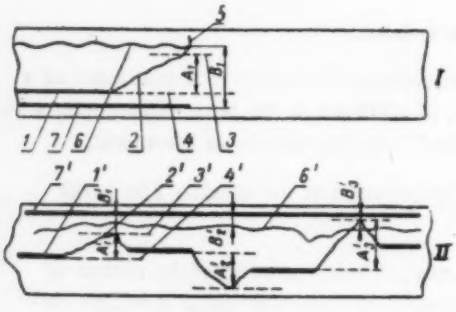

Fig. 3.

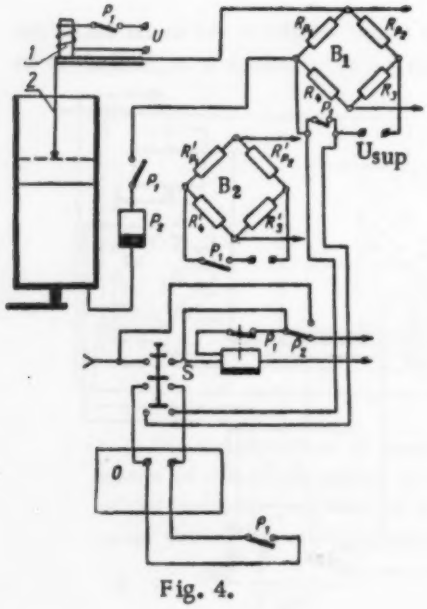

Fig. 4.

By means of push-button S_1 contacts 3-4, 5-6 and 13-14 are closed, thus connecting the volumeter circuit and the supplies to bridge circuit B_2. The bending of the volumeter measuring-plate is registered on the oscillograph (recorder) by line 2 shown in Fig. 3 [1], and the deformation of the scale's beam by line 6. The operation of the volumeter produces a sharp kick on the oscillogram (Fig. 3, position 5).

Ordinate A_1, determined as the distance between lines 3 and 4, represents the smelt volume, and ordinate B_1 represents its weight. The required density is $D = B_1/A_1$.

For a convenient use of the areometer a table is compiled which provides the value of density in terms of the ordinates A and B; this table can be replaced by a graph.

Automatic operation is provided by adding a relay unit to the manually operated areometer.

The schematic of the automatic areometer is shown in Fig. 4.

By depressing push-button switch S supplies are connected to oscillograph O, to the volumeter bridge B_1 and the slow-operating relay P_1.

The film will record (Fig. 3, position II) the zero position of the volumeter as line 1' and the zero position of the scales as line 7', which is recorded by the reference oscillograph galvanometer. When relay P_1 operates (push-button switch S has already been depressed) it closes all its contacts shown on the circuit and locks itself in this position. The contacts of relay P_1 provide supplies to the scales bridge circuit B_2, the volumeter bridge circuit B_1, the volumeter electromagnet 1 and continue supplying the oscillograph chart-propelling mechanism. The operation of the volumeter produces line 2' on the oscillogram (Fig. 3,

position II) [1]. As soon as the volumeter measuring pin 2 touches the smelt, relay P_2 operates, since the contacts of relay P_1 have already prepared the required circuit. Relay P_2 is also slow-operating. Relay P_2 disconnects the locking contacts of relay P_1, but connects the supply of the latter. When relay P_2 de-energizes it provides the possibility for relay P_1 to lock itself again. Operation of the volumeter provides the next kick on the oscillogram.

The de-energizing of relay P_2 after the operation of relay P_1 repeats the entire cycle of operations [1].

Ordinates A'_1, A'_2 and A'_3 determine the volume of the liquid (smelt) and ordinates B'_1, B'_2 and B'_3 the weight of this volume.

The adjustment of the timing of the interlocked relays (P_1–P_2) provides a reliable operation of the areometer.

With a low recording speed and a long film (paper) and the use of large cassettes, it is possible to obtain a continuous recording for 12-15 hours, thus making it possible to use this instrument both under laboratory and production conditions.

The use of highly sensitive oscillographic galvanometers provides direct recording without an amplifier.

Systematic errors in the areometer are obviated by calibrating the entire circuit against a standard measuring channel.

The error of the instrument can be determined in the following manner. We find $\delta^2 = \delta_s^2 + \delta_g^2 + \delta_o^2 + \delta_a^2$, where δ_s is the strain-gauge transducer error; δ_g is the oscillograph galvanometer limiting error; δ_o is the oscillogram reading limiting error; δ_a is the amplifier limiting error (if it is being used).

There is also an additional measuring error due to the variation in the position of the areometer case when the scale beam is bent.

This error is determined by the formula

$$\Delta D = 100 D \frac{\Delta L}{H} \%,$$

where D is the density measurement; ΔL is the additional bending of the scales beam; H is the height of the smelt level in the container.

This error is systematic and can be accounted for by calculating the total error from formula

$$\delta_{\Sigma} = \delta + D.$$

Normally this error is small. Thus, calculations have shown that it normally amounts to about 2.5%. If special measuring circuits are used this error can be reduced a little.

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DIFFERENTIAL THERMAL LEVEL-DISPLACEMENT TRANSDUCER

B. M. Gol'tsman

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 50-51, December, 1960

For checking and controlling the level of molten aluminum in a bath we used a thermal transducer of displacements, which measures level oscillations in the range of ±2 mm with respect to a mean position with an error of ±0.04 mm. The construction of the transducer is shown in Fig. 1. The filament of a differential chromel-alumel thermocouple 3, which runs along the axis of a small tube-shaped oven, is stretched between beams 1 and

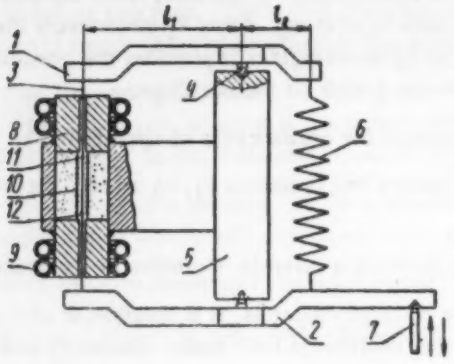

Fig. 1.

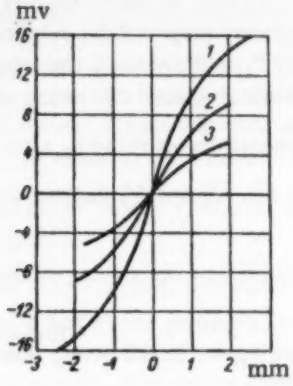

Fig. 2.

2. The beams are fixed on needle-point bearings 4 to a stationary base 5. Each beam has two supports at a distance of 20 mm from each other (Fig. 1 only shows one support). The beam arms l_1 and l_2 are respectively equal to 30 and 12 mm. One of the thermocouple ends is fixed to the beam through an insulating bush. Spring 6 presses the needle-point bearings 4 to the base and tensions the thermocouples. The lower beam is connected by means of a quartz rod 7 to a float which rests on the surface of the smelt. The float consists of a flat trough made of steatite, a material which is inert with respect to molten aluminum. The surface of the float bottom is equal to 9 cm^2. The thermocouple filament is displaced with respect to the oven with a changing smelt level in the bath. The transverse displacement of the filament due to the turning of the beam does not exceed 0.07 mm.

The thermocouple filament diameter is 0.1 mm. The distance between the junctions 11 and 12 is equal to 8 mm. The thermocouple is connected to a recording control potentiometer. The brass body 8 of the oven is cooled by means of water running through tubes 9 (with an external diameter of 2 mm), which are braised to the body of the oven. The length of the oven is 24 mm, its external diameter is 10 mm, and the diameter of its channel is 1.2 mm. The heating nichrome helix 10 (wire diameter 0.5 mm), wound turn against turn, is secured inside the oven by means of fireproof cement. The length of the helix is approximately equal to the distance between the thermocouple junctions (8 mm). The cement layer between the extreme windings of the helix and the brass body of the oven is 0.5 mm thick. The oven is supplied from a step-down transformer connected to a ferro-resonant stabilizer of 200 w.

Figure 2 shows the relation of the thermocouple emf to the displacement of the filament with respect to its position for a thermal emf equal to zero. In the latter position the thermocouple junctions are placed symmetrically with respect to the heater helix. Curves 1, 2, and 3 were obtained for helical heater temperatures equal to 435, 295 and 190°C respectively (the helix heater currents were 6.9, 5.5 and 4.2 amp respectively). For a helix temperature of 435°C the measurement error does not exceed 0.04 mm; for supply voltage variations of 20% the transducer readings do not vary by more than 4%. After an instantaneous displacement of the filament by 4 mm from one extreme position to the other, the temperature of the thermocouple junction attains a steady state in 2.5 seconds. Any effects of electromagnetic fields on the transducer readings could not be observed and, therefore, there was no need for screening. Ambient temperatures vary the sensitivity of the transducer but have hardly any effect on its zero position. Thus, if the transducer is used as a zero indicating instrument, it is possible to rely for the cooling of the oven body on natural convection without employing running water.

SUMMARY

The inertia of the above transducer is smaller than that of a recorder. The construction of the transducer is simple, its size is small, it has no power reaction between the moving and stationary parts, and it is possible to connect the transducer directly to the recorder.

CALIBRATION OF HORIZONTAL TANKS BY A COMBINED METHOD

N. V. Nikolin

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 51-52, December, 1960

At present the calibration of horizontal cylindrical or elliptical tanks is made by means of geometrical or volumetric methods. Calibration by means of the first method involves errors in determining the geometric dimensions of the tank, and calibration by means of the second method involves errors in measuring the volume of the liquids poured into the tank, its height in the tank and the error in interpolating the data for the actual levels of liquids when compiling the calibration table.

These errors can be reduced if the tank is calibrated by the suggested combined method, in which the total volume of the tank is determined by the volumetric method, but the subsequent calculations of a calibration table in steps of one centimeter are made by means of a table of coefficients K_c, K_s and K_k according to the accepted methods of calibrating the cylindrical part of the bottoms of the tank [1].

The combined method, like the geometrical method, is based on the assumption that the geometrical form of the tank is regular (within the tolerances), and that it is placed horizontally.

When calibrating by the suggested method, the cylindrical tanks should be divided into two groups, those with flat bottoms and those with convex bottoms.

Tanks with flat bottoms are first filled by means of measures of different sizes and the total capacity of the tank is determined; next this figure is multiplied by the values of coefficient K_c of the volumetric filling of the tank cylinder, values which correspond to level heights in steps of one centimeter.

In tanks with convex bottoms the full capacity is first determined by the volumetric method, and then the capacity of the two bottoms or the capacity of the cylindrical part of the tank is determined by means of the geometrical method. The capacity of the two bottoms is equal to the full capacity of the tank less the capacity of the cylindrical part of the tank calculated by means of the geometrical method; and the capacity of the cylindrical part of the tank is equal to the full capacity less the calculated capacity of the two bottoms.

The calculated diameter of the cylindrical part of the tank is determined from the formula

$$D = \sqrt{\frac{V_{c.t.}}{0.7854 L_c}}.$$

Elliptical tanks are calibrated by the same method as the horizontal cylindrical tanks, by first determining volumetrically the capacity of the tank, and then taking the vertical axis of the ellipse as the diameter for calculations.

Example 1. It is required to calibrate in steps a cylindrical tank which has a spherical bottom and is placed horizontally. The total capacity of the tank determined by the volumetric method is V_t = 10,540 liters, the length of the cylindrical part of the tank is L_c = 4.312 mm, the rise in the convexity of the bottom is f = 340 mm, the diameter of the bottom base is D_b = 1.697 mm.

Let us calculate the volume of the spherical bottom.

$V_b = 0.5236f\,(0.75\,D_b^2 + f^2)$ = 405 liters, the capacity of the cylindrical part of the tank is $V_{ct} = V_t - 2V_b$ = = 9.730 liters, and the mean diameter used for calculations is D_t = 169.5 cm.

Further calibration of the cylindrical part of the tank and its spherical bottoms is carried out by the normal methods [1].

Example 2. It is required to calibrate in steps an elliptical tank which has flat bottoms and is placed horizontally. The full capacity of the tank is determined by the volumetric method as V_t = 2,854 liters, and its vertical axis is b = 620 mm.

The capacity of an elliptical tank filled to a certain level is $V_f = V_t K_f$, where K_f is the coefficient of volumetric filling. This coefficient can be replaced by the coefficient K_c used for determining the filling of a cylinder of a diameter equal to the diameter of a circumference inscribed in the ellipse. In this case $K_f = K_c$ and H : b = H : D.

In the above example the values of H : D are equal to 1 : b = 0.016129 = 0.0161 for a filling height of the tank H = 1 cm; and to 2 : b = 0.0323 for a filling height of the tank of H = 2 cm, etc.

These values of H : D correspond to the following values of K_c [1]: for H = 1 cm, K_c = 0.00344; for H = 2 cm, K_c = 0.00977, etc.

The amount of liquid poured into this tank equals: for H = 1 cm, $V_{p_1} = V_t K_c = 2840 \cdot 0.00344 = 9.8$ liters; for H = 2 cm, $V_{p_2} = 2840 \cdot 0.00977 = 27.7$ liters, etc.

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CALIBRATION IN CENTIMETER STEPS OF UNDERGROUND HORIZONTAL TANKS WITH CYLINDRICAL BOTTOMS

E. N. Lessig

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 52-53, December, 1960

Underground tanks with cylindrical bottoms are best placed in such a position that the generating lines of their bottoms are vertical. This reduces the amount of excavation and simplifies the erection of their foundations.

For calibrating underground horizontal tanks of this type by means of the combined volumetric and geometrical method the author of this article has calculated the filling coefficients K_{cb} for cylindrical bottoms in relation to the filling height H of the tank and its diameter D.

The required volume of liquid, which is at an arbitrary level in both the cylindrical bottoms [1], is equal to

$$V_{fb} = \frac{2}{3}(4R^2 - y^2)\sqrt{R^2 - y^2} - 2R^2 y \cos^{-1}\frac{y}{R} \qquad (1)$$

if the filling of the cylinder does not exceed half its volume, and it is

$$V_{fb} = \frac{16}{3}R^3 - \left[\frac{2}{3}(4R^2 - y^2)\sqrt{R^2 - y^2} - 2R^2 y \cos^{-1}\frac{y}{R}\right] \qquad (2)$$

if the filling is above that value.

$\frac{H}{D}$	K_{cb}	$\frac{H}{D}$	K_{cb}	$\frac{H}{D}$	K_{cb}	$\frac{H}{D}$	K_{cb}	$\frac{H}{D}$	K_{cb}	$\frac{H}{D}$	K_{cb}	$\frac{H}{D}$	K_{cb}
0.010	0.002	0.158	0.112	0.290	0.255	0.440	0.429	0.590	0.606	0.740	0.779	0.890	0.932
0.020	0.006	0.166	0.120	0.300	0.266	0.450	0.441	0.600	0.618	0.750	0.790	0.900	0.941
0.030	0.010	0.170	0.124	0.310	0.278	0.460	0.453	0.610	0.629	0.760	0.801	0.910	0.949
0.040	0.016	0.178	0.132	0.320	0.289	0.470	0.465	0.620	0.641	0.770	0.812	0.920	0.957
0.050	0.022	0.186	0.141	0.330	0.301	0.480	0.476	0.630	0.653	0.780	0.823	0.930	0.964
0.060	0.028	0.190	0.145	0.340	0.312	0.490	0.488	0.640	0.665	0.790	0.834	0.940	0.972
0.070	0.036	0.200	0.153	0.350	0.324	0.500	0.500	0.650	0.676	0.800	0.845	0.950	0.978
0.080	0.043	0.210	0.165	0.360	0.335	0.510	0.512	0.660	0.688	0.810	0.855	0.960	0.984
0.090	0.051	0.220	0.177	0.370	0.347	0.520	0.524	0.670	0.699	0.818	0.861	0.970	0.990
0.100	0.059	0.230	0.188	0.380	0.359	0.530	0.535	0.680	0.711	0.830	0.876	0.980	0.994
0.110	0.068	0.240	0.199	0.390	0.371	0.540	0.547	0.690	0.722	0.838	0.884	0.990	0.998
0.120	0.076	0.250	0.210	0.400	0.382	0.550	0.559	0.700	0.734	0.850	0.895	1.000	1.000
0.130	0.086	0.260	0.221	0.410	0.394	0.560	0.571	0.710	0.745	0.860	0.905		
0.140	0.095	0.270	0.232	0.420	0.406	0.570	0.582	0.720	0.757	0.870	0.914		
0.150	0.105	0.280	0.243	0.430	0.418	0.580	0.594	0.730	0.768	0.880	0.924		

In formulas (1) and (2) R is the internal radius of the cylindrical bottom, y is the vertical distance from the axis of the tank to the surface of the poured liquid.

If the volume of liquid in the bottoms

$$V_{f.b} = 2K_{cb}V_{cb} \tag{3}$$

is expressed in terms of the filling coefficient K_{cb} for cylindrical bottoms in relation to distance y we shall have

$$K_{cb} = \frac{1}{2R}\left[\left(1-\frac{y^2}{4R^2}\right)\sqrt{R^2-y^2} - \frac{3}{4}y\cos^{-1}\frac{y}{R}\right] \tag{4}$$

if the filling of the tank does not exceed half its volume and

$$K_{cb} = 1-\frac{1}{2R}\left[\left(1-\frac{y^2}{4R^2}\right)\sqrt{R^2-y^2} - \frac{3}{4}y\cos^{-1}\frac{y}{R}\right] \tag{5}$$

if the filling exceeds that value.

In formula (3) V_{cb} is the volume of a single cylindrical bottom equal to $8R^3/3$; and K_{cb} is the filling coefficient for bottoms of cylindrical tanks calculated from (4) and (5).

The numerical values of coefficient K_{cb} in relation to ratio H/D are given in the table attached.

The above table of the filling coefficients for cylindrical bottoms makes it possible to compute in steps of one centimeter calibration tables for underground horizontal tanks of any diameter.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.

ESSAYS AND REVIEWS

STATE OF REFERENCE AND CALIBRATION WORK IN THE U. S. A. IN THE SPHERE OF RADIOELECTRONICS*

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 53-55, December, 1960

Considerable attention is being paid in the USA at the present time, due to the rapid development of the radio-electronic industry, to the establishment of standards and reference equipment in the sphere of radio measurements. The existing measuring equipment, however, does not provide the required accuracy in the production of radio-electronic equipment. Certain firms are attempting to fill the lack of such equipment by means of their own efforts, but the instruments made by them cannot ensure the required accuracy and uniformity of measurements, since they are not based on the state standards of the National Bureau of Standards (NBS).

In this connection the NBS laboratory in Boulder has been carrying out in recent years an extensive research program of radio measurement methods and establishing reference measuring equipment for all the types of radio measurements and frequency ranges. Standards and reference equipment have been developed or improved for measuring frequency, attenuation, voltage, impedance, noise, field strength, interference, admittance, and electrical and magnetic parameters of materials. Moreover, a special laboratory is studying the property of radio materials by means of the latest methods.

Impedance measurements in the UHF range. The laboratory has developed three types of reference loads: a tunable, movable, matched load for rectangular waveguides, which has practically no reflections; precision short-circuiting sections; semicircular irregularities whose reflection factor is accurately calculated for given dimensions and wavelengths. The tunable, movable, matched waveguide load has a VSWR of 1.0002, which corresponds to an attenuation of the reflected wave exceeding 80 db. Careful mechanical finish provides accurate tuning and minimum variations in the reflection factor.

The precision short-circuiting waveguide section consists of a silver-plated waveguide segment in which the distance between the flange and the short-circuiting plane is equal to a 1/4 wavelength. This section provides at 10,000 Mc a VSWR approaching 5,140, which corresponds to a voltage reflection factor of 0.99961. For certifying the section an attenuator had to be used with an error of calibration smaller than 0.0001 db. Such an accuracy exceeds that of any previously made attenuators. This led to the development of a new attenuation measuring method which is described below.

The inductive semicircular irregularities are intended for use as reference loads over a wide range of VSWR values. The measured VSWR values of these loads agree with the calculated ones with an error less than 0.1%. The required accuracy of measuring the VSWR was attained by using an improved reflectometer.

At present work is in progress for extending these methods to rectangular guides of other dimensions and to coaxial systems.

Accurate attenuation measurements. For calibrating attenuators with an error not exceeding 0.0001 db a method based on measuring UHF power by means of a bolometric bridge was used. The UHF oscillator signal of a stable amplitude was fed through the tested attenuator to the bolometric head placed in a constant tem-

* This review was compiled from the materials of the USA National Bureau of Standards Bulletin – Technical News Bulletin, 43, 12, 1959.

perature water tank. The signal amplitude is stabilized by means of a feed-back which uses as its sensing element another bolometer also placed in a water tank. The attenuation increment is determined by the UHF power increment as $A = 10 \log P_1/P_2$.

The UHF power is measured by means of a precision bolometric self-balancing dc bridge. This method eleminates the error due to the efficiency of the bolometric head, since it is not the absolute value of power which is measured, but the ratio of two powers and the attenuation does not depend on the power level. This fact has been confirmed experimentally.

Two errors were analyzed, that due to mismatching and the other due to the accuracy of measuring the balancing direct current. The equipment provides a matching up to a VSWR of 1.005. For this condition the error in measuring the direct current should not exceed 0.1% + 1 μw. A statistical analysis of the measurement results has shown that the circuit satisfies these requirements providing great care is taken in the manufacture of the attenuator.

Atomic standard frequencies. Reference frequencies and precise time signals are transmitted by the WWV and WWVH radio stations. In addition the experimental radio station in Boulder transmits a frequency of 60 kc. The NBS radio laboratory checks continuously the frequency of the WWV radio station by means of atomic standards. The comparison is carried out with an error not exceeding 10^{-11}.

Experiments have shown that frequency standards based on atomic constants are more accurate than astronomical or quartz crystal standards. Atomic clocks have no secular variations inherent in astronomical clocks and do not age like the quartz clocks. Moreover, they can measure time and frequency rapidly, whereas other systems require months and even years for evaluating time.

The latest improvements in atomic clocks provide new possibilities for their use in science and technology. Thus, their use raises considerably the resolution of spectroscopic methods of investigating molecules, atoms and atomic nuclei. Accurate measurements of time provide the possibility of investigating the effect of seasons, tides, and movements of air on the rotation of the earth. It becomes possible to study by means of atomic clocks the effect of rarefied gases and magnetic fields on the movement of planets and satellites. It is intended to use atomic clocks for an experimental verification of the special and general theory of relativity.

The operation of the atomic clock is based on the use of a beam of cesium atoms. When the cesium atoms pass from one energy state to another electromagnetic energy of a strictly defined frequency is either absorbed or radiated. For an isolated atom the difference in the energies of the two states and, hence, the absorbed or radiated frequency, is constant. In practice, the presence of many atoms makes it impossible to obtain a precise and stable frequency; however, the equipment produced by the NBS is the most accurate frequency standard.

At present the cesium standard provides an accuracy of $7 \cdot 10^{-11}$. The newly made second atomic standard has a slightly higher accuracy. These two atomic standards (atomichron) and a precision quartz oscillator are regularly compared to each other. In the new standard provision is made for the use of thallium, which has several advantages as compared with cesium.

The two NBS ammonia molecular oscillators are used for studying atomic transitions and for comparing frequencies. The NBS atomic standards are regularly compared with frequency standards of other countries.

Electronic calibration center. The basic objectives of the NBS Electronic Calibration Center established in 1958 consist of comparing the working standards and calibrating reference instruments for measuring voltage, power, and impedance against the NBS standards. The center consists of three departments.

The low frequency (0 - 30 kc) department calibrates resistors, bridges, potentiometers, capacitors, inductance coils, standard cells, potential dividers and instrument transformers. Recently the center received a transformer-type capacitance bridge which extends the calibration range down to 1 μpf. In 1960 it is planned to extend the frequency range for calibrating voltage and current transformers from 60 to 400 cps.

The unit of voltage in the form of a saturated standard cell is kept in an air cabinet at a constant temperature. The newly-made oil bath will raise the accuracy of the standard by a factor of five.

The high frequency (30 kc - 300 Mc) department calibrates reference voltages, powers, impedances, at-

tenuations and field strengths. Calibration is carried out mostly at fixed frequencies of 30, 100, 300 kc and 1, 3, 10, 100, and 300 Mc.

The laboratory has made a new precision cutoff attenuator for a frequency of 30 Mc by means of which it is possible to measure attenuation differences smaller than 0.001 db. It is calibrated with an error smaller than 0.01 db. In 1960 attenuators for 100 and 300 Mc will also be designed.

Voltage meters are calibrated at fixed frequencies in the range of 30 kc - 400 Mc; the equipment in the range of 30 kc - 100 Mc has a voltage range of 0.2 to 500 v, and at frequencies of 300 to 400 Mc a range of 0.2 to 100 v. An equipment for measuring in the range of 1 μ v to 0.1 v is being completed. The greater part of the equipment has a calibration error of 3%, but in the range of 30 kc to 10 Mc the error amounts to 2% and in 1960 it is proposed to reduce it to 0.25%.

The UHF (over 300 Mc) department is designing and improving equipment for precision measurements of power, impedance, attenuation, frequency and noise. Devices with coaxial lines cover the range of 300 - 4000 Mc. It is intended to cover with waveguide devices the range of 2,600 to 40,000 Mc, and to measure frequency up to 75,000 Mc.

Waveguide power meters are calibrated in the range of 8,200 - 12,400 Mc with an error up to 1%. An equipment for measuring power in waveguide systems in the range of 2,600 - 3,950 Mc is being completed.

An equipment for measuring the VSWR in the range of 8,200 - 12,400 Mc is also being completed; the expected error of this equipment is 0.5 - 0.1%.

Waveguide attenuators are calibrated in the range of 2,600 - 18,000 Mc. In 1960 equipment for measuring in the range of 18,000 to 26,500 Mc will be completed. The range for calibrating coaxial attenuators is being extended to 5,600 Mc.

The development of a UHF noise-measuring equipment was started in 1959, and instruments for measuring in the range of 8,200 - 12,400 Mc have already been made.

In the first year's operation of the calibrating center 14,122 calibrations of 2,074 instruments were made. Of this number two-thirds are instruments of the Department of Defense and one third instruments belonging to the radio-electronic industry.

Radio materials. The NBS laboratories are working on an equipment for studying the interaction between electromagnetic waves and matter. It is intended to use new methods of investigation: molecular beams, radiospectroscopy, gyrators, and nuclear, ferromagnetic and paramagnetic resonance. By means of these methods problems connected with the solid and liquid state, dielectric and magnetic phenomena will be investigated and physical constants determined.

In the UHF range attention will be mainly paid to determining the tensor permeability and the dielectric properties of ferrites at frequencies of 1,060, 3,100 and 9,200 Mc. The tensor permeability of ferrites in weak dc fields is being studied. The results thus obtained are applied in designing new UHF ferrite instruments (insulators, phase shifters, modulators).

Permittivity and loss angles are measured in the range of 0.1 - 10^{10} cps at temperatures of -100 to 500°C. The NBS has developed a method of measuring small loss angles (of the order of 0.000001) at a frequency of 1 Mc.

V. R.

ORION-EMG OSCILLOSYNCHROSCOPE TYPE 1548*

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 55-57, December, 1960

At the Hungarian industrial exhibition in Moscow held in 1960 one of the exhibits was an Orion-EMG oscilloscope type 1548 designed for measuring time and suitable for investigating and measuring time parameters of periodic and aperiodic signals. This oscilloscope can be best applied for measuring pulse signals in television, radar, pulse modulating devices, and for checking and calibrating pulse generators.

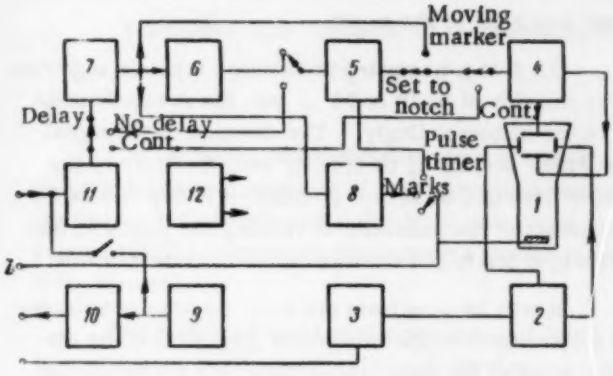

Fig. 1. 1) Cathode-ray tube; 2) vertical wide-band amplifier; 3) input attenuator; 4) sweep generator; 5) generator of rectangular pulses A; 6) variable precision delay unit; 7) generator of rectangular signals R; 8) notch generator (marker); 9) master oscillator of synchronizing pulses; 10) variable delay unit for synchronizing pulses (of the master oscillator); 11) synchronizing amplifier and selector; 12) power pack.

Fig. 1 shows the oscilloscope block-schematic.

The balanced output of the vertical wide-band amplifier 2 is connected to the vertical deflecting plates of the cathode-ray tube 1. It is also possible to feed signals directly to plates with the amplifier disconnected.

A special advantage of this instrument consists in the fact that the amplifier output is connected to two jacks on the front panel, thus making it possible to use an external tube voltmeter for measuring the amplitude of various wave forms.

The input attenuator (amplitude divider) 3 makes it possible to measure large signals. The dividing ratio does not depend on frequency.

The sweep generator (saw-tooth voltage generator) 4 is connected to the horizontal plates of the cathode-ray tube 1, and can operate both in a single-sweep (triggered) and continuous condition.

The variable precision delay unit 6 consists of a circuit for obtaining a voltage rising linearly with time (saw-tooth) for the comparing device and the delayed pulse amplifier.

The instrument can operate continuously when it is used as a normal wide-band oscilloscope and in a single-sweep (triggered condition), when it is used as a pulse oscilloscope (or synchroscope). In the latter condition there are two operation versions: "without delay" (as a normal synchroscope) and "with delay".

Since the operations of a normal oscilloscope and a synchroscope (without delay) are well known, we shall only examine the operation of the instrument "with delay".

In this case two versions are possible depending on the duration of the measured intervals.

1. For long sweeps (100, 1,000 μ sec) and internal triggering the circuit operates in the following manner: the pulses from the master oscillator 9 are fed through the variable delay unit 10 to the output terminals and trigger the generator under test. The output pulses of the generator under test are fed to the input of the vertical wide-band amplifier 2 or directly to the plates of the cathode-ray tube 1. The second pulse from the master oscillator 9 is transmitted through the synchronizing amplifier 11 and starts generator 7 R.

* A resume of the material sent to the editorial board by the information service of the Hungarian Chamber of Commerce.

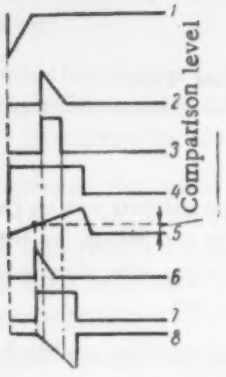

Fig. 2. 1) pulse at output of the master oscillator of synchronizing pulses; 2) delayed pulse at the output of the variable-delay synchronizing-pulse unit; 3) pulse of the generator under test; 4) pulse at the output of the generator of rectangular pulses R; 5) pulse in the comparison circuit of the precision delay unit; 6) delayed pulse at the output of the delay unit; 7) pulse at the output of the generator of rectangular pulses A; 8) pulse of the sweep generator.

The output pulses of the generator of rectangular signals R trigger the sweep generator 4 and the variable precision delay unit 6, in which the reference voltage used for comparisons is adjusted by means of a linear "helipot" potentiometer. At the instant the reference voltage becomes equal to the saw-tooth voltage, a second delayed pulse is formed which starts generator 5 of rectangular signals A. Its output pulses fed to the cathode of the cathode-ray tube 1 produce a bright spot on the screen of the oscilloscope. This spot (mark) can be placed by means of the "helipot" potentiometer over any point of the sweep.

2. If it is necessary to examine separate segments of a duration of 5, 10 or 25 μ sec, the sweep duration is re-set correspondingly. The duration of the signal may then amount up to 1,000 μ sec. Contrary to the above description, sweep generator 4 is now started by the pulses of the generator of rectangular pulses A, and nothing is fed to the cathode of the cathode-ray tube 1.

It will be seen from the time diagram of voltages in various parts of the instrument (Fig. 2) that the displacement of the pulse under test along the sweep can be attained by changing the delay of the output synchronizing pulse, or by displacing the sweep itself with respect to the pulse by means the variable precision delay unit. In the latter case the large scale of the "helipot" potentiometer is first adjusted to 0 then the beginning of the measured time interval is made to coincide with the mark on the scale (grid) placed in front of the cathode-ray tube screen. By turning the knob of the "helipot" potentiometer, thus varying the delay, the end of the time interval is made to coincide with the same mark. The reading is taken off the potentiometer scale.

Brief Technical Characteristics

Vertical amplifier: a frequency range of 5 cps - 8 Mc; deviation of the frequency characteristic with respect to 1 kc is ± 3 db.

The attenuator provides voltage division ratios of 1:3, 1:10, 1:30 and 1:100.

The sweep generator has a frequency range of 20 cps - 200 kc in continuous operation; and single-sweep durations without delay of 5, 10, 25, 100, 1,000, 4,500 and 10,000 μ sec. These durations with delay are: 5, 10 and 25 μ sec for a delay of 100 μ sec; and 10 and 25 μ sec for a delay of 1,000 μ sec.

The master oscillator has a pulse repetition frequency in the range of 80 - 2,000 cps; it has either positive or negative pulses, of an amplitude not less than 15 v.

For external triggering either positive or negative pulses are used of an amplitude of about 25 v; the delay of synchronizing pulses is 4 - 20 μ sec; the range of the precision delay unit, that is, the measured time interval, amounts to 0.05 - 1,000 μ sec with a measuring error of $\pm$ 1%.

The mark generator has a period of 10 μsec $\pm$ 0.5%.

The set operates from 110 and 220 v, 50 and 60 cps mains.

Its consumption is 450 w, and its weight 70 kg.

MATERIAL RECEIVED BY THE EDITORIAL BOARD

QUALIFIED PERSONNEL FOR THE FACTORY TEST LABORATORIES

Ya. E. Medovnik

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 57-58, December, 1960

The industrial establishments are now checking an increasing number of their own measuring instruments, and the inspection agencies of the Committee reserve the right only to supervise the reference measures and measuring instruments and a restricted number of commercial measures and instruments. The problem of training qualified personnel for the factory agencies supervising the condition of the measuring equipment is, therefore, essential.

The technical level of the personnel of factory test laboratories and control and checking stations cannot be considered satisfactory. Although the factory inspection agencies have recruited in recent years workers with technical or full secondary education, there are still many people in the laboratories without a completed secondary education. There are very few experts with a higher technical education. There are few engineers at the head of test laboratories in the establishments of the Khar'kov Sovnarkhoz (Council of National Economy), and this duty is not always performed by persons with a secondary technical education.

The local agencies of the Committee are partly responsible for this unsatisfactory state of affairs. When the plants which desire to obtain the right for testing their own measuring equipment are inspected by the GKL (State Inspection Laboratory) representatives, they are mainly interested in the degree to which the factory laboratories are equipped with measures, measuring the testing instruments, and neglect such an important factor as the staffing of the measuring equipment inspection agencies with metrologically trained personnel. The Committee's inspection agencies on the basis of regulations 12-58 must, before granting a permit to an establishment, verify the ability of the factory test laboratory personnel to cope with their new responsibilities, and to disqualify plants which lack trained experts. This will prompt the factories to staff their laboratories with qualified personnel and to train people for such jobs more intensively.

In order to train metrological experts the Ministry of Higher and Specialized Secondary Education of the USSR should study the possibility of establishing at several higher technical institutes special faculties dealing with electrical and thermal instruments, mechanical, linear and angle-measuring instruments and radio instruments. These faculties should train engineers for leading central test laboratories in factories, specialized test departments, as well as engineers for the inspection agencies of the Committee of Standards, Measures and Measuring Instruments and for the instrument-making industry.

An important role in training the personnel for factory test laboratories can be played by the Odessa State Technical Measurements School, provided, in accepting students, preference is given to persons engaged directly in supervising measuring equipment. However, one school cannot cope with the task of supplying industrial establishments and inspection agencies of the Committee with personnel having a secondary technical education. It seems advisable to establish another technical school in one of the eastern regions of the country. In addition to this the agencies of the Committee should render considerable assistance to the various establishments by systematically training test laboratory personnel in specially provided courses. In this respect considerable experience has been gained by the Khar'kov State Institute of Measures and Measuring Instruments (KhGIMIP) and the largest GKLs.

Following the setting up of the Khar'kov Sovnarkhoz the training of personnel for factory test laboratories of the region was organized in a planned manner. On the suggestion of the KhGIMIP the Sovnarkhoz instructed its education committee to include in its plan the training of measuring equipment workers. At the same time the Sovnarkhoz instructed its subordinated establishments and organizations to submit to the KhGIMIP their requests for training personnel in various spheres of measurements. On the basis of these requests the institute trains groups of 25-30 persons. The general subjects (foundations of measurement techniques, the state service of measures and measuring instruments, etc.) are taken by the whole group, specialized training is carried out in the institute laboratories.

The education committee pays the tutors, provides premises, equips its library with technical books, and acquires textbooks and laboratory equipment.

Formerly the institute trained 40 - 50 industrial workers (mainly in linear and angular measurements), whereas in 1959 180 persons were trained and in 1960 over 200 workers in all spheres of measurement.

The institute receives requests from establishments in other regions for training their measurement equipment workers. In the majority of cases the institute cannot accede to these requests, since it has not sufficient room to expand any further its practical training. Moreover, the education committee of the Khar'kov Sovnarkhoz cannot finance establishments outside its economic region.

It would be expedient for 1st grade GKLs, which have teachers and possess facilities for practical training, to organize training centers for measurement equipment workers. In the Ukraine, for instance, such centers could be organized by the Kiev, Dnepropetrovsk, Odessa, and L'vov GKLs in addition to the one already existing in Khar'kov. In conjunction with the Sovnarkhozes the GKLs should start organized training of factory test laboratory personnel. This would greatly help our industry to maintain the measurement equipment at the required technical level.

ECONOMY IN THE USE OF ELECTRICAL ENERGY

M. D. Kalennikov

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 58-59, December, 1960

In the letter of the CPSU Central Committee entitled "Rational Utilization of Electrical Energy in our National Economy", concrete measures are outlined for its economic utilization .

As the result of certain measures taken by the Kiev GKL (State Inspection Laboratory), it has saved more than 25% of its normal consumption of electrical energy. This was achieved by switching off equipment during intervals in work, improving electrical wiring, forbidding unnecessary use of electrical heaters, re-arranging the lighting, etc.

The laboratory paid special attention to helping industrial establishments to rationalize their use of electrical energy. The laboratory's plan of work includes the checking of the correct metering and measuring of electrical energy at establishments in the engineering, pottery, building materials, and local industries.

As a rule these establishments did not meter electrical energy in separate shops. In certain plants three-phase power was measured by means of single-phase meters, and meters were found which were below the technical standards.

The Kiev GKL personnel together with factory experts prepared a plan for saving electrical energy.

As a result of this in the Belich woodworking plant alone 26,000 kw-hr of electrical energy was saved in the 1st quarter of 1960 by stopping the leakage of compressed air, equal distribution of the load between phases,

replacing motors of excessive power, etc.

At the pottery plants capacitors were installed to raise cos φ, motors of excessive power were replaced, idle running of equipment was reduced, fluorescent lighting introduced, lighting distribution rearranged, etc. As a result of all these measures the consumption of electrical energy at these plants was reduced by 49,000 kw-hr.

An important part in introducing a rational use of electrical energy was played by the fact that all the information obtained in checking the utilization of electrical energy in the plants of the Sovnarkhoz and in local industry was presented to the appropriate administrations, which instructed their subordinate organizations to improve the utilization of electrical energy. The Sovnarkhoz administrations rendered practical assistance to various plants in eliminating as speedily as possible the defects in the utilization of electrical energy. In order to check the execution of their instructions the administration set a time limit for the directors to report on the improvement in the utilization of energy in their plants.

In our opinion the state inspection laboratories of measuring equipment should assist industrial establishments in economizing in the use of their electrical energy.

INSTRUMENT RECEPTION BUREAUS IN THE STATE INSPECTION LABORATORIES

V. V. Petropavlovskii

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 59-60, December, 1960

In recent years many state inspection laboratories of measuring equipment have been transferred to new quarters with separate premises for their instrument reception bureaus. The majority of laboratories have special reception personnel.

The existence in the GKLs (State Inspection Laboratories) of special reception bureaus housed in large premises provides every possibility for efficient reception, storage and issue of instruments with the provision of maximum facilities for the owners of instruments who submit them for checking to the GKLs. The existence of reception bureaus will save the testing departments the necessity of encumbering their premises with instruments, which they can take straight from the reception bureau and return them to the bureau immediately after testing. This is very important, since it should be taken into account that the reception bureau has to deal in the majority of cases with expensive and valuable instruments, and all the reference and standard measures submitted for checking to the GKL. Many clients judge the efficiency of the GKL by the service they obtain in the reception bureaus.

Unfortunately many GKLs pay little attention to their reception bureaus, and consequently the work of the bureaus provokes justified complaints by the GKL customers.

Some of the bureaus work only part of the day and on certain days are closed altogether. The specified dates for checking instruments are often broken, thus forcing the clients to make another journey to the GKL. Often the reception bureaus keep for a long time the tested instruments without notifying the clients that they are awaiting collection. This leads to overstocking and congestion in the bureau, deterioration of storage conditions and errors in issuing the instruments.

There are instances when receptionists accept for checking obviously defective, dirty or incomplete instruments. It is easy to understand the customer's indignation when, on returning in a few days' time to collect his instrument, he finds that weights were rejected due to corrosion, a manometer due to a broken glass, scales

owing to absence of a pad, etc. These defects could and should have been noticed by the receptionist, who should not have accepted such instruments for checking.

Certain GKLs do not accept testing charges in cash, and demand that even small sums, for instance, 4 rubles for checking an electricity meter, should be sent by postal order, whereas there exist receipt books whose use up to certain amounts is permitted by the Committee.

Many bureaus lack tables on which the customers could unpack their instruments, dust them and on receipt repack them. It is wrong for the laboratory to refuse to store crates in which the instruments have been brought.

In many bureaus there is no shelving, no organized system of placing or storing the instruments.

Many reception bureaus will not lend the customers dusters or small tools, such as screwdrivers, hammers, etc. The majority of the reception bureaus do not exhibit the price-list for testing, the conditions on which the instruments are accepted for checking, the opening hours, the manner of payment for checking, the addresses and telephone numbers of instrument-repair organizations, etc. Considerable inconvenience is caused to the customers by the absence of telephones in the reception bureaus.

Many of these shortcomings are due, to a great extent, to the fact that the GKL receptionists lack the required education, are badly acquainted with the instruments, fill incorrectly or untidily the technical questionnaires, do not clearly understand the rate of charges for testing. Untrained receptionists cannot ensure an efficient storage of instruments, provide the required information to the customer, etc.

It should be noted that certain heads of the GKLs have already started improving the work of their reception bureaus, for instance, by appointing metrologically trained personnel as receptionists, making it possible to entrust them with carrying out certain simple checking in the reception bureau itself. For this purpose several reference scales, a load manometer, etc., are installed in the reception bureaus. This eliminates unnecessary moving of the instruments inside the GKL building, speeds up testing, and makes it possible speedily to return certain instruments after checking.

It is the duty of every GKL worker to help improve the work of the reception bureaus, thus helping to raise the reputation of the laboratory. An efficient operation of a reception bureau helps to a considerable extent in raising the productivity of labor and fulfilling the plans of the GKL.

It should always be borne in mind that the work of a state inspection laboratory of measuring equipment begins at the reception bureau.

ORGANIZING THE PRODUCTION OF TEST SETS

I. M. Veisas

Translated from Izmeritel'naya Tekhnika, No. 12, p. 60, December, 1960

One of the reasons for the low quality of measuring equipment in current use is the lack of test sets. In order to avoid handicraft methods in making test sets specified by appropriate instructions it is advisable to start their centralized manufacture.

In order to exchange experiences gained in this respect conferences of the heads of factory test laboratories in groups of plants should be more widely organized by the GKLs.

INFORMATION

IN THE INTERNATIONAL METROLOGICAL ORGANIZATIONS

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 60-61, December, 1960

In October 1960 the Metric Convention was signed by Indonesia, one of the largest countries in south-east Asia, and in November by Venezuela.

At the 11th General Conference on Weights and Measures on October 20, 1960, half the membership of the International Committee of Weights and Measures was re-elected. The following members of the Committee were re-elected: Astin (USA), Burdun (USSR), Howlett (Canada), Danjon (France), Krishman (India), Otero (Spain), Sandoval Vallarta (Mexico), Schtula-Hertz (Austria), and Esserman (Australia).

The International Committee of Weights and Measures elected as its president R. Fleweg (FRG), as vice-president L. Howlett (Canada), and as secretary D. Cassinis (Italy).

Academician A. Perard, honorary director of the International Bureau of Weights and Measures, died in Paris on October 21, 1960. A. Perard worked for the International Bureau of Weights and Measures from 1905 to 1951, and in the capacity of its director from 1936 to 1951.

A. Perard worked untiringly for the development of the scientific activity of the International Bureau in the sphere of the measurements of mass, length, electrical quantities and in the sphere of thermometry and especially of interferometry, thus assisting the new definition of the meter in terms of a light wavelength.

For his outstanding scientific achievements A. Perard was elected full member of the French Academy of Sciences.

The International Bureau of Weights and Measures has arranged for a session in the first quarter of 1961 of the four working parties of the International Committee's Consultative Committee on standards for measuring ionizing radiations (on standards for x-ray and gamma-ray radiations, on standards for radioactive preparations, for neutron sources, and on radium standards).

In the second half of 1960 Indonesia, the United Arab Republic and Venezuela joined the convention which establishes the International Organization of Legislative Metrology.

The council of the presidium of the International Organization of Legislative Metrology has decided to hold the 2nd General Conference on Legislative Metrology in Vienna (Austria) on June 13-18, 1962.

The holding of the 2nd International Conference on Measurement Techniques (IMEKO) is planned for June 1961 in Budapest. Prof. V. O. Arutyunov and Prof. A. N. Gavrilov represent the USSR on the IMEKO organizing committee.

An international exhibition of measuring instruments will be held at the Great Exhibition Hall of the Champs Élysées in Paris on May 9-16, 1961. The exhibition will include the traditional spring exhibitions of scientific instruments and materials, which are held annually by the French Physical Society (in Paris) and by the British Physical Society (in London).

The first issue of the "Bulletin of the International Organization of Legislative Metrology" issued by the International Bureau of Legislative Metrology has appeared in Paris.

According to the decision of the 2nd session of the International Committee of Legislative Metrology which was held in October 1958, this bulletin will appear once a quarter in French.

The first issue contains the following articles:

1. Mr. Jacob (chief metrologist, director of the Belgian Metrological Service, president of the International Committee of Legislative Metrology), International Organization of Legislative Metrology.

2. G. Burdun (Deputy chairman of the Committee of Standards, Measures and Measuring Instruments attached to the Council of Minister of the USSR, vice-president of the International Committee of Legislative Metrology), the State Service of Measures and Measuring Instruments in the USSR.

3. Z. Rausher (Director of the Polish National Bureau of Measures), Quantities and Measuring Units.

4. The French Service of Measuring Instruments. Draft resolution on measuring units and checking of measuring instruments.

5. A Rast (Technical inspector of the Austrian Federal Bureau of Metrology), Mobile Test Laboratory of the Austrian Service.

6. J. Yasnorzhevskii (International Bureau of Legislative Metrology). Establishment of a Center for Metrological Documentation by means of Bibliographical Microphotographs.

In addition to these articles the issue carries materials dealing with the work and structure of the International Organization of Legislative Metrology.

1. Problems under consideration.

2. Structure and method of work of the reporting-secretariats.

3. List of subjects submitted for consideration, accepted for consideration or not yet accepted.

4. List of member-states of the International Organization of Legislative Metrology (July, 1960).

5. List of states, corresponding-members of the IOLM.

6. List of members of the International Committee of Legislative Metrology.

7. List of the presidium of the IOLM

8. Composition of the International Bureau of Legislative Metrology.

EXHIBITION OF DUTCH MEDICAL AND SCIENTIFIC INSTRUMENTS

Translated from Izmeritel'naya Tekhnika, No. 12, p. 61, December, 1960

An industrial exhibition of Dutch medical and scientific instruments, organized for the first time in the USSR, was held in Moscow on November 11-27, 1960, in the hall of the Polytechnical Museum. The exhibition was organized by the Dutch firm of Stemmler-Imeks, which comprises 9 large instrument-making plants. In addition to numerous medical apparatus and devices, measuring instruments for science and industry were also exhibited. Some of these instruments have already been described in the journal "Measurement Techniques" (No. 11, 1960).

A series of sensitive portable galvanometers, microammeters and millivoltmeters exhibited by the firm Kipp attracted considerable attention. The shockproof grade 1.0 microvoltammeter type "Mikrova" included in this series is equipped with a luminous display scale 200 mm long; the instrument has 10 current ranges, from 2 μ a (125 ohm) to 50 ma (1.2 ohm), and 10 voltage ranges, from 0.5 mv to 15 v, with a resistance of 500 kilohm/v. The same firm exhibited an original automatic recording grade 1.0 microvoltammeter type "Micrograph BD" for recording in rectangular coordinates on a chart 210 mm wide; the instrument has 12 measuring ranges: 6 current ranges from 0.1 μ a (resistance of 120 ohm) to 5 μ a (0.25 ohm) and six voltage ranges from 0.05 mv (resistance of 500 ohm) to 2.5 mv (25,000 ohm), as well as a device for displacing the zero to the left or right to a distance greater than the length of the whole scale. The instrument uses a photogalvanometric transducer with photovaristers fed from a dc supply, and a stabilized eight-transistor amplifier whose output is connected to a reversible motor with a tachometer generator which makes up a high speed (1 sec) servosystem. The instrument is also supplied with a second pen for recording events, which plots (on pressing a button) rectangular pulses on the edge of the chart. The chart is propelled at a speed varying from 60 to 14,400 mm/hr (15 speeds, 5 for each type of instrument); a facility is provided for lifting the recording pens off the chart by pressing a button. The instrument is supplied with a second slidewire for remote transmission of readings or for operation as an integrating element of a computer.

The firm of Ekaf, which specializes in making electronic instruments for nuclear physics, exhibited an automatic recording rack-mounted gamma-spectrometer. This instruments consists of seven units: a stabilized source of supplies with voltages up to 1,700 v and a stability of 0.005%; a linear amplifier with a gain of 20 - 10,000; a single-channel differential analyzer (resolution time of 2 μ sec); a count speed meter measuring up to 30 kc; an instrument for scanning spectra supplied with a precision potentiometer and a motor drive; an electronic counter and a recording instrument with two pens. The instrument operates with signals received from scintillation detectors combined with photomultipliers.

The Nieaf testing sets are attractively finished. This firm exhibited a series of "Select" miniature instruments of 100 x 78 x 38 mm weighing 250 g with a scale 54 mm long, including various voltammeters, bridges, lux-meters, a phase-sequence indicator for a three-phase network, as well as other service and laboratory instruments.

The firm Enraf-Nonius exhibited x-ray installations and apparatus for x-ray analysis, various integrating goniometers, photographic cameras, comparators, microdensimeters, etc.

The firm Godart-Meinhart, which specializes in instruments for investigating the functioning of lungs, exhibited combined measuring sets for use in surgery and physiological investigations.

The firm Elter and Viterma among other products exhibited two versions of multichannel electronic encephalographs with programming devices.

COMMITTEE OF STANDARDS, MEASURES, AND MEASURING INSTRUMENTS

AMENDMENTS TO INSTRUCTION 15 - 52 FOR CHECKING STATIONARY UNEQUAL ARM (PLATFORM) SCALES

Translated from Izmeritel'naya Tekhnika, No. 12, pp. 62-63, December, 1960

The Committee of Standards, Measures and Measuring Instruments has put into effect amendments to instruction 15-52 which take into consideration the new requirements of the GOSTs (State All-Union Standards) for automobile and railroad car weighbridges and new methods for checking these bridges.

Section 3 reads as follows:

"All stationary scales and their foundations must be made according to drawings duly approved; moreover automobile weighbridges must satisfy the requirements of GOST 7862-56 and railroad car weighbridges those of GOST 9020-59."

The requirements regarding the finish of the beam have been changed, namely, the tinning and polishing of the beam is forbidden, and only its nickel-plating or chrome-plating is allowed, and the wording of section 11 has been changed accordingly.

The length of sidings to the weighbridges has been changed from 20 m to 15 m by section 53 of the instruction.

A note has been added to section 62:

"In steppes and woodless regions it is permitted in special cases, left to the discretion of the heads of state inspection laboratories, to install automobile weighbridges without shelter, providing there exist means for protecting the weighbridge from atmospheric precipitations by covering it with a tarpaulin, straw or rush mats, shields, etc."

In the case of loose-weight and indicating scales it is permitted, if reference weights are not available in quantities sufficient to check the maximum capacity of the scales, to use in addition to the method described in section 92 of the instruction, also the following method:

"For scales whose sensitivity and variations in readings do not exceed for 10% loads the value of 0.1% of the above load the following methods of checking are permitted.

"A loaded truck weighing 80 - 90% of the weighbridge capacity is driven across a locked weighbridge at a speed of 5 km/hr first in one and then in the opposite direction. The change in the balance of the unloaded bridge after each drive should not exceed 0.01% of the maximum capacity of the weighbridge. The truck is then driven onto the bridge from two opposite directions and weighed each time; the difference in these weighings should not exceed 0.02% of the mean weight of the loaded truck. At the same time the sensitivity of the bridge is determined by varying the weight of the loaded truck by 0.05% and noting the deflection of the mobile from the stationary pointer which should be not less than 5 mm. If the weighbridge satisfies all the above requirements, a carriage with a pan for weights is attached to the end of the beam near the balance pointer and the weighbridge is brought to equilibrium by means of the zero regulator. Reference 3rd grade weights to the value of 1 ton are then placed in the middle of the platform and the weighbridge is brought back to balance by means of reference 2nd grade weights placed on the carriage pan, thus determining the 'value of 1 ton' P_1, i.e., the mass of 2nd grade weights which balance 1 ton of reference 3rd grade weights placed on the center of the platform.

"Having removed the weights from the platform it is reloaded by the previously measured truck whose rear wheels should be placed over the left-hand side weight-supporting knife-edge bearings. The truck is then weighed by means of 2nd grade weights placed on the pan of the device and a reading A_1 is obtained. One ton of 3rd grade reference weights is then placed on the platform over the right-hand side knife-edge bearings and a new reading B_1 obtained. The truck is then moved to a position where its rear wheels are over the right hand side knife-edge bearings and balanced by means of 2nd grade weights which provide a reading A_2. One ton of 3rd grade reference weights is again placed on the platform over the left-hand side knife-edge bearings and a new reading of B_2 obtained.

"The mass of the loaded truck is then obtained in terms of the reference weights placed on the pan from:

$$M_1=\frac{A_1+A_2}{2};$$

and the 'value of 1 ton' is obtained from two weighings:

$$P_2=B_1-A_1;\quad P_3=B_2-A_2;$$

the mean 'value of 1 ton' P is obtained from three readings:

$$P=\frac{P_1+P_2+P_3}{3};$$

the computed mass of the loaded truck M_c is obtained by dividing the mass of the 2nd grade weights M_1 which balance the loaded truck by the 'value of 1 ton' P:

$$M_c=\frac{M_1}{P}.$$

"Having determined the computed mass of the loaded truck, the reference weights are removed both from the platform and the pan of the weighbridge, and the truck is weighed by means of the sliding weights, thus determining its actual mass M_a. By comparing the actual mass of the truck M_a with its computed mass M_c the error of the weighbridge is determined. If the difference between M_a and M_c does not exceed 0.1% of M_c, the weighbridge is considered suitable for use."

The note to section 92 is replaced by the following note:

"The minimum amount of reference weights required for checking scales by the method outlined in section 92 must amount to not less than 25% of the capacity of the scales."

The technique of checking railroad car weighbridges is changed and a provision made that the accuracy of their readings should be checked only by means of the reference weighing flatcar (checking with a load of

Without a load	For 1/10 of the maximum load	For checking the additional scale	For checking by means of a reference weighing flatcar	For checking by means of a reference weighing flatcar with the addition of reference weights	For determining the constancy of weighbridge reading with the load approaching the capacity
1/10,000 of the maximum load	10 kg	10 kg	1/1000 of the mass of the reference weighing flatcar	1/1000 of the actual loading of the weighbridge	1/1000 of the mass of the car used for determining the constancy of weighbridge readings

2.5 tons is abolished), and therefore section 78 of the instruction and references in section 96 and notes to section 93 on checking by means of a 2.5 ton load are deleted and paragraphs 1 and 2 of section 95 are reworded in the following manner:

"Single railroad car weighbridges are checked by means of a reference weighing flatcar which is placed consecutively in positions 1, 2 and 3, shown in Fig. 16. If a flatcar supplied with jacks is available it is placed and lifted over each pair of weight-carrying knife-edge bearings."

Moreover, section 80 is supplemented by the following note:

"In checking railroad car weighbridges weights are not placed over each bearing but over a pair of weight carrying kinife-edge bearings."

Section 97 is supplemented by the following words:

"If a flatcar equipped with jacks is available it is placed and lifted over each pair of weight-carrying knife-edge bearings."

The checking of weighbridges at 10% of their carrying capacity should be carried out only when they leave the manufacturing plant until the time when mechanized measuring equipment (weight-checking railroad cars) becomes available.

I. NEW SPECIFICATIONS FOR MEASURES AND MEARURING INSTRUMENTS APPROVED BY THE COMMITTEE

New Instructions for Checking Measures and Measuring Instruments
(Registered in August-November, 1960)
Translated from Izmeritel'naya Tekhnika, No. 12, p. 63, December, 1960

Instruction 156-60 for checking high precision 1st and 2nd grade reference platinum resistance thermometers. Replacing instruction 156-54. Effective from June 1, 1961.

Instruction 161-60 for checking reference platino-iridium-platinum thermocouples and high precision thermocouples. Replacing instruction 161-54. Effective from June 1, 1961.

II. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE AS THE RESULT OF STATE TESTS AND PASSED FOR USE IN THE USSR

(Registered in October-November, 1960)
Translated from Izmeritel'naya Tekhnika, No. 12, p. 63, December, 1960

Ampere-volt-watt-meters, trade mark D552 of the Kiev Sovnarkhoz (Council of National Economy). State register number 1399-60.

Induction coils, trade mark R547, of the Kiev Sovnarkhoz. State register number 1400-60.

Electrical measuring sets, trade mark K50, of the Kiev Sovnarkhoz. State Register No. 1401-60.

Shock, vibration and jolt-proof rack-mounted frequency meters, trade mark D156 of the Leningrad Sovnarkhoz. State Register No. 1402-60.

Rack-mounted flush ammeters and voltmeters with luminous indicators, trade mark M 135, of the Leningrad Sovnarkhoz. State Register No. 1403-60.

Rack-mounted galvanometers with aluminous indicators, trade mark M 135/1-10, of the Leningrad Sovnarkhoz. State Register No. 1404-60.

Rack-mounted ammeters and voltmeters, trade mark E330, of the Krasnodar Sovnarkhoz, State Register No. 1405-60.

Portable amperevoltohm-meters, trade mark M360, of the Krasnodar Sovnarkhoz. State Register No. 1406-60.

Stationary current transformers, trade mark TK and TSh, of the Moscow City Sovnarkhoz. State Register No. 1407-60.

Resistance boxes, trade mark MSR-60, of the L'vov Sovnarkhoz. State Register No. 1408-60.

Resistance boxes, trade mark R555, of the Kiev Sovnarkhoz. State Register No. 1409-60.

Reference thermistor bridges, trade mark MTO-1, of the Krasnodar Sovnarkhoz. State Register No. 1410-60.

Electronic phase meters, trade mark EF-1, of the Kiev Sovnarkhoz. State Register No. 1411-60.

Universal radiometers, trade mark "TISS", of the Belorussian Sovnarkhoz. State Register No. 1412-60.

1st Grade linear meters, trade mark MSh1R, of the Moscow Regional Sovnarkhoz. State Register No. 1413-60

Grease refractometers, trade mark RZh, of the Kiev Sovnarkhoz. State Register No. 1414-60.

Automatic hydrogen gas analyzers TP-1120, of the Academy of Sciences USSR. State Register No. 1415-60.

Movable, loose-weight platform scales of 500 and 1000 kg capacity of the Mogilev Regional Executive Committee. State Register No. 1416-60.

Methane analyzers, trade mark IM-3, of the Khar'kov Sovnarkhoz. State Register No. 1417-60.

III. MEASURES AND MEASURING INSTRUMENTS EXCLUDED FROM THE STATE REGISTER

Translated from Izmeritel'naya Tekhnika, No. 12, p. 63, December, 1960

Current transformers 0-49. State Register No. 617.

Resistance boxes MSL-49. State Register No. 1016-56.

1st Grade Linear meters. State Register No. 316.

FROM THE PAGES OF OTHER JOURNALS

Archiv für technisches Messen

No. 290, March, 1960

Krake. Measurements of molten metal temperatures. Block-schematic of the measuring device, thermocouple and protective jacket; servicing the equipment.

Grundler. Measuring short-circuit currents in photocells. General principles of measuring short-circuit currents and open-circuit voltages of resistive linear two-terminal networks and their application to the measurement of the radiation of light by means of photocells. Various measuring circuits.

Narges. Application of electronic multirange measuring devices for measuring the pressure and temperature of fluids flowing through constrictors, part II (for beginning see ATM, No. 288, pp. 7-9). Block-schematic of the transducer with several thermocouples for measuring temperature in various parts of the pipes. Method of calibrating the temperature and pressure transducers.

No. 291, April, 1960

The Hannover industrial fair of 1960. Review of the exhibited control devices, computers, etc.

Schultze. Optical focusing measurements. The physical basis of the control and measuring equipment for checking the focusing and refraction in optical systems.

Strojnik. Stabilized high-tension rectifiers for supplying electron microscopes and devices in applied electronics.

The principle of operation of dc high-tension sources, methods of smoothing ripple after rectification. Stabilization of ac and dc voltages.

Instruments and Control Systems

No. 2, February, 1960

Kaufman. Acceleration generators. Five methods of producing accelerations for testing and calibrating accelerometers are described.

Cortelyou. Centrifugal method for measuing flow. Theoretical investigation of the centrifugal method and a comparison with the diaphragm method of measuring flow.

Aronson. Checking the quality in the manufacture of bearings and measuring vibrations.

Measures et controle industrial

No. 277, June, 1960

Dembneau. Potentialities of permeameters with detachable coils. Design and production of instruments. Examples of the application of permeameters for plotting magnetization curves and measuring permeability by means of alternating currents and at high frequencies.

Ludvig (?). A new method of making wire strain-gauges. Is based on coating with the conducting layer in vacuum.

No. 278, July, 1960

Arguments in favour of accepting the international system of units.

Jacob. Metrological numbers.

Sedoz. Elimination of random quantities in measuring systems which use wire strain-gauges. Theoretical investigation of a double Wheatstone bridge for precision compensation of temperature effects. Practical application of the theoretical research.

The Review of Scientific Instruments

No. 2, February 1960

Hall. Device for obtaining ultrahigh pressure at high temperatures. Description of an equipment for prolonged maintenance of a pressure of 100,000 atm at 2,000°C.

Koppola. Measurement of the cathode temperature of commercial cathode-ray tubes.

No. 3, March, 1960

Dauphini and Preston-Thomas. Bridge-circuit direct-reading resistance thermometers.

Purcell and Keeler. A sensitive gas analyzer based on the measurement of thermal conductivity. Design and schematic of the electronic part. The use of alternating current for supplying the thermal transducers. Decrease drift and higher sensitivity.

Brog and Milford. Precision high-current regulator. A transistorized regulator circuit and a rectifier with 50 amp silicon diodes. Applied for controlling the current through an electromagnet.

Riemer and Sage. High-pressure manometers.

Feingerätetechnik

No. 6, June, 1960

Bachman. Manometer with an elastic sensing element. Brief report on the latest improvements in the design of manometers.

Bechstedt. The use of analytical measuring instruments in industry. Design of gas analyzers, gas spectrometers for the infrared region and density meters for gas.

No. 7, July, 1960

Gunzler. A method of measuring colors by means of metallic interferometer filters.

Orshanskii, Pavlenko and Shutov. Present-day conditions and trends in the development of analytical measuring instruments.

Wiemer (?). Control of mass production details by means of pneumatic measuring instruments.

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Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR
Russian Original Dated November, 1960

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Soviet Journals Available in Cover-to-Cover Translation

ABBREVIATION	RUSSIAN TITLE	TITLE OF TRANSLATION	PUBLISHER	TRANSLATION BEGAN Vol.	Issue	Year
AÉ	Atomnaya énergiya	Soviet Journal of Atomic Energy	Consultants Bureau	1	1	1956
Akust. zh.	Akusticheskii zhurnal	Soviet Physics – Acoustics	American Institute of Physics	1	1	1955
	Antibiotiki	Antibiotics	Consultants Bureau	4	1	1959
Astr(on). zh(urn).	Astronomicheskii zhurnal	Soviet Astronomy–AJ	American Institute of Physics	34	1	1957
Avto(mat). svarka	Avtomaticheskaya svarka	Automatic Welding	British Welding Research Association (London)		1	1959
	Avtomatika i Telemekhanika	Automation and Remote Control	Instrument Society of America	27	1	1956
	Biofizika	Biophysics	National Institutes of Health*		1	1957
	Biokhimiya	Biochemistry	Consultants Bureau	21	1	1956
Byull. éksp(erim). biol. i med.	Byulleten' éksperimental'noi biologii i meditsiny	Bulletin of Experimental Biology and Medicine	Consultants Bureau	41	1	1959
DAN (SSSR) / Dokl(ady) AN SSSR	Doklady Akademii Nauk SSSR	The translation of this journal is published in sections, as follows:				
		Doklady Biochemistry Section	American Institute of Biological Sciences	106	1	1956
Life Sciences		Doklady Biological Sciences Sections (Includes: Anatomy, biophysics, cytology, ecology, embryology, endocrinology, evolutionary morphology, genetics, histology, hydrobiology microbiology, morphology, parasitology, physiology, zoology sections)	American Institute of Biological Sciences	112	1	1957
Life Sciences		Doklady Botanical Sciences Sections (Includes: Botany, phytopathology, plant anatomy, plant ecology, plant embryology, plant physiology, plant morphology sections)	American Institute of Biological Sciences	112	1	1957
Chemical Sciences		Proceedings of the Academy of Sciences of the USSR, Section: Chemical Technology	Consultants Bureau	106	1	1956
Chemical Sciences		Proceedings of the Academy of Sciences of the USSR, Section: Chemistry	Consultants Bureau	106	1	1956
Chemical Sciences		Proceedings of the Academy of Sciences of the USSR, Section: Physical Chemistry	Consultants Bureau	112	1	1957
Earth Sciences		Doklady Earth Sciences Sections (Includes: Geochemistry, geology, geophysics, hydrogeology, mineralogy, paleontology, petrography, permafrost sections)	American Geological Institute	124	1	1959
Earth Sciences		Proceedings of the Academy of Sciences of the USSR, Section: Geochemistry	Consultants Bureau	106-123	1 6	1957-1958
Earth Sciences		Proceedings of the Academy of Sciences of the USSR, Sections: Geology	Consultants Bureau	106-123	1 6	1957-1958
Mathematics		Doklady Soviet Mathematics	The American Mathematics Society	131	1	1961
Physics		Soviet Physics–Doklady (Includes: Aerodynamics, astronomy, crystallography, cybernetics and control theory, electrical engineering, energetics, fluid mechanics, heat engineering, hydraulics, mathematical physics, mechanics, physics, technical physics, theory of elasticity sections)	American Institute of Physics	106	1	1956
Physics		Proceedings of the Academy of Sciences of the USSR, Applied Physics Sections (does not include mathematical physics or physics sections)	Consultants Bureau	106-117	1	1956-1957
Derevoobrabat. prom-st'.	Derevoobrabatyvayushchaya promyshlennost'	Wood Processing Industry	Timber Development Association (London)		9	1959
	Élecktrosvyaz	Telecommunications	Massachusetts Institute of Technology*		1	1957
Éntom(ol). oboz(renie)	Éntomologicheskoe obozrenie	Entomological Review	American Institute of Biological Sciences	38	1	1959
Farmakol. (i) toksikol(ogiya)	Farmakologiya i toksikologiya	Pharmacology and Toxicology	Consultants Bureau	20	1	1957
FMM	Fizika metallov i metallovedenie	Physics of Metals and Metallography	Acta Metallurgica*	5	1	1957
Fiziol. zhurn. SSSR (im. Sechenova)	Fiziologicheskii zhurnal im. I. M. Sechenova	Sechenov Physiological Journal USSR	National Institutes of Health*		1	1957
Fiziol(ogiya) rast.	Fiziologiya rastenii	Plant Physiology	American Institute of Biological Sciences	4	1	1957
	Geokhimiya	Geochemistry	The Geochemical Society		1	1958
FTT	Fizika tverdogo tela	Soviet Physics–Solid State	American Institute of Physics	1	1	1959
Izmerit. tekh(nika)	Izmeritel'naya tekhnika	Measurement Techniques	Instrument Society of America		1	1959
Izv. AN SSSR, O(td). Kh(im). N(auk)	Izvestiya Akademii Nauk SSSR: Otdelenie khimicheskikh nauk	Bulletin of the Academy of Sciences of the USSR: Division of Chemical Sciences	Consultants Bureau		1	1952

continued

Izv. AN SSSR, O(td). T(ekhn). N(auk): Met(all). i top.	(see Met. i top.)				
Izv. AN SSSR Ser. fiz(ich).	Izvestiya Akademii Nauk SSSR: Seriya fizicheskaya	Bulletin of the Academy of Sciences of the USSR: Physical Series	Columbia Technical Translations	1	1954
Izv. AN SSSR Ser. geofiz.	Izvestiya Akademii Nauk SSSR: Seriya geofizicheskaya	Bulletin (Izvestiya) of the Academy of Sciences USSR: Geophysics Series	American Geophysical Union	1	1954
Izv. AN SSSR Ser. geol.	Izvestiya Akademii Nauk SSSR: Seriya geologicheskaya	Izvestiya of the Academy of Sciences of the USSR: Geologic Series	American Geological Institute	1	1958
Kauch. i rez.	Kauchuk i rezina	Soviet Rubber Technology	Research Association of British Rubber Manufacturers	18	1 1959
	Kinetika i kataliz	Kinetics and Catalysis	Consultants Bureau	1	3 1960
	Koks i khimiya	Coke and Chemistry USSR	Coal Tar Research Association (Leeds, England)		1 1958
Kolloidn. zh(urn).	Kolloidnyi zhurnal	Colloid Journal	Consultants Bureau	14	1 1952
	Kristallografiya	Soviet Physics – Crystallography	American Institute of Physics	2	1 1957
Metalov. i term. obrabot. metal.	Metallovedenie i termicheskaya obrabotka metallov	Metal Science and Heat Treatment of Metals	Acta Metallurgica	6	1 1958
	Metallurg	Metallurgist	Acta Metallurgica		1 1957
Met. i top.	Metallurgiya i topliva	Russian Metallurgy and Fuels	Eagle Technical Publications		1 1960
Mikrobiol.	Mikrobiologiya	Microbiology	American Institute of Biological Sciences	26	1 1957
OS	Optika i spektroskopiya	Optics and Spectroscopy	American Institute of Physics		6 1959
	Pochvovedenie	Soviet Soil Science	American Institute of Biological Sciences		1 1958
	Priborostroenie	Instrument Construction	British Scientific Instrument Research Association		1 1959
Pribory i tekhn. éks(perimenta)	Pribory i tekhnika éksperimenta	Instruments and Experimental Techniques	Instrument Society of America		1 1957
Prikl. matem. i mekh.	Prikladnaya matematika i mekhanika	Applied Mathematics and Mechanics	American Society of Mechanical Engineers		1 1958
PTÉ	(see Pribory i tekhn. éks.)				
	Problemy Severa	Problems of the North	National Research Council of Canada		
Radiotekh.	Radiotekhnika	Radio Engineering	Massachusetts Institute of Technology*	12	1 1957
Radiotekh. i élektronika	Radiotekhnika i élektronika	Radio Engineering and Electronics	Massachusetts Institute of Technology*	2	1 1957
	Stanki i instrument	Machines and Tooling	Production Engineering Research Assoc.		1 1959
	Stal'	Stal (In English)	Iron and Steel Institute		1 1959
Stek. i keram.	Steklo i keramika	Glass and Ceramics	Consultants Bureau	13	1 1956
Svaroch. proiz-vo	Svarochnoe proizvodstvo	Welding Production	British Welding Research Association		4 1959
Teor. veroyat. i prim.	Teoriya veroyatnostei i ee primenenie	Theory of Probability and Its Applications	Society for Industrial and Applied Mathematics		1 1956
Tsvet. Metally	Tsvetnye metally	Nonferrous Metals	Primary Sources		1 1960
UFN	Uspekhi fizicheskikh Nauk	Soviet Physics – Uspekhi (partial translation)	American Institute of Physics	66	1 1958
UKh	Uspekhi khimii	Russian Chemical Reviews	The Chemical Society (London)		1 1960
UMN	Uspekhi matematicheskikh nauk	Russian Mathematical Surveys	London Mathematical Society	15	1 1960
Usp. fiz. nauk	(see UFN)				
Usp. khim(ii)	(see UKh)				
Usp. matem. nauk	(see UMN)				
Usp. sovr. biol.	Uspekhi sovremennoi biologii	Russian Review of Biology	Oliver and Boyd	48	1959
Vest. mashinostroeniya	Vestnik mashinostroeniya	Russian Engineering Journal	Production Engineering Research Assoc.	4	1959
Vop. gem. i per. krovi	Voprosy gematologii i perelivaniya krovi	Problems of Hematology and Blood Transfusion	National Institutes of Health*	1	1957
Vop. onk.	Voprosy onkologii	Problems of Oncology	National Institutes of Health*	1	1957
Vop. virusol.	Voprosy virusologii	Problems of Virology	National Institutes of Health*	1	1957
Zav(odsk). lab(oratoriya)	Zavodskaya laboratoriya	Industrial Laboratory	Instrument Society of America	25	1 1959
ZhAKh Zh. anal(it). khimii	Zhurnal analiticheskoi khimii	Journal of Analytical Chemistry USSR	Consultants Bureau	7	1 1952
ZhETF Zh. éksperim. i teor. fiz.	Zhurnal éksperimental'noi i theoreticheskoi fiziki	Soviet Physics–JETP	American Institute of Physics	28	1 1955
ZhFKh Zh. fiz. khimii	Zhurnal fizicheskoi khimii	Russian Journal of Physical Chemistry	The Chemical Society (London)		7 1959
ZhMÉI Zh(urn). mikrobiol. épidemiol. i immunobiol.	Zhurnal mikrobiologii, épidemiologii i immunobiologii	Journal of Microbiology, Epidemiology and Immunobiology	National Institutes of Health*		1 1957
ZhNKh Zh(urn). neorgan(ich). khim(ii)	Zhurnal neorganicheskoi khimii	The Russian Journal of Inorganic Chemistry	The Chemical Society (London)		1 1959
ZhOKh Zh(urn). obshch(ei) khimii	Zhurnal obshchei khimii	Journal of General Chemistry USSR	Consultants Bureau	19	1 1949
ZhPKh Zh(urn). prikl. khimii	Zhurnal prikladnoi khimii	Journal of Applied Chemistry USSR	Consultants Bureau	23	1 1950
ZhSKh Zh(urn). strukt. khimii	Zhurnal strukturnoi khimii	Journal of Structural Chemistry	Consultants Bureau	1	1 1960
ZhTF Zh(urn). tekhn. fiz.	Zhurnal teknicheskoi fiziki	Soviet Physics–Technical Physics	American Institute of Physics	26	1 1956
Zh(urn). vysshi. nervn. deyat. (im. Pavlova)	Zhurnal vysshei nervnoi deyatel'nosti (im. I. P. Pavlova)	Pavlov Journal of Higher Nervous Activity	National Institutes of Health*		1 1958

*Sponsoring organization. Translation through 1960 issues is a publication of Pergamon Press.

SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET TECHNICAL PERIODICALS

AN SSSR	*Academy of Sciences, USSR*
FIAN	*Physics Institute, Academy of Sciences USSR*
GITI	*State Scientific and Technical Press*
GITTL	*State Press for Technical and Theoretical Literature*
GOI	*State Optical Institute*
GONTI	*State United Scientific and Technical Press*
Gosénergoizdat	*State Power Press*
Gosfizkhimizdat	*State Physical Chemistry Press*
Goskhimizdat	*State Chemistry Press*
GOST	*All-Union State Standard*
Gostekhizdat	*State Technical Press*
GTTI	*State Technical and Theoretical Press*
IAT	*Institute of Automation and Remote Control*
IF KhI	*Institute of Physical Chemistry Research*
IFP	*Institute of Physical Problems*
IL	*Foreign Literature Press*
IPF	*Institute of Applied Physics*
IPM	*Institute of Applied Mathematics*
IREA	*Institute of Chemical Reagents*
ISN (Izd. Sov. Nauk)	*Soviet Science Press*
IYap	*Institute of Nuclear Studies*
Izd	*Press (publishing house)*
LÉTI	*Leningrad Electrotechnical Institute*
LFTI	*Leningrad Institute of Physics and Technology*
LIM	*Leningrad Institute of Metals*
LITMiO	*Leningrad Institute of Precision Instruments and Optics*
Mashgiz	*State Scientific-Technical Press for Machine Construction Literature*
MGU	*Moscow State University*
Metallurgizdat	*Metallurgy Press*
MOPI	*Moscow Regional Pedagogical Institute*
NIAFIZ	*Scientific Research Association for Physics*
NIFI	*Scientific Research Institute of Physics*
NIIMM	*Scientific Research Institute of Mathematics and Mechanics*
NIKFI	*Scientific Institute of Motion Picture Photography*
NKTM	*People's Commissariat of the Heavy Machinery Industry*
Obrongiz	*State Press of the Defense Industry*
OIYaI	*Joint Institute of Nuclear Studies*
ONTI	*United Scientific and Technical Press*
OTI	*Division of Technical Information*
OTN	*Division of Technical Science*
RIAN	*Radium Institute, Academy of Sciences of the USSR*
SPB	*All-Union Special Planning Office*
Stroiizdat	*Construction Press*
URALFTI	*Ural Institute of Physics and Technology*
TsNIITMASh	*Central Scientific-Research Institute of Technology and Machinery*
VNIIM	*All-Union Scientific Research Institute of Metrology*

NOTE: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us — *Publisher.*

Publication of a "Soviet Instrumentation and Control Translation Series" by the Instrument Society of America has been made possible by a grant in aid from the National Science Foundation, with additional assistance from the National Bureau of Standards for the journal *Measurement Techniques.*

Subscription rates have been set at modest levels to permit widest possible distribution of these translated journals.

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